RICE IN INDIA

Kashmiri woman with her harvest of paddy

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FOREWORD

Rice is the most important food crop of India. Nearly three-fourths of the people in the country subsist on it. Besides, with its cultivation varying between 75 to 80 million acres, or roughly one-third of the total world rice acreage, India is the largest rice growing country in the world. The annual production of clean rice is about 27 to 29.5 million tons which is 31 per cent. of the world production.

The crop is grown under diverse conditions in the country from almost sea-level to elevations of 6,000 ft. The soils vary from loams and clays to shallow laterites, with reaction ranging from extremely acidic to highly alkaline. At places, cultivation is done in 15 to 20 ft. deep water ; at others, it is carried on with a meagre rainfall of 20 inches. In some areas, a single crop is taken once a year ; in other areas, three paddy crops are grown in succession annually on the same land. Again, the crop may be of 70 days' duration or may take six to seven months to mature, and may be grown in summer or autumn or winter. The problems which this great diversity poses to research workers can well be imagined.

At present there are over 280 varieties of rice grown in the country. Many of these are suitable for particular regions only and if grown in other areas prove failures. The tendency to evolve specialised varieties has led to serious difficulty inasmuch as the increasing number of strains is making the task of pure seed multiplication and distribution more and more complicated. Again, there is the problem of breeding, flood and salinity resistant varieties suited to the conditions obtaining in some of the major rice growing areas in the country. To these difficulties may be added the problems of breeding varieties for double cropping, cultivation of 'wet' paddy lands, controlling pests and diseases and improving the quality of rice.

The Central Rice Research Institute, Cuttack, has been doing very useful work ever since it was set up. The State Departments of Agriculture are also giving considerable attention to the crop, either from their own resources or with the assistance provided by the Indian Council of Agricultural Research. However, in spite of all this, the average yield in India is one of the lowest in the world. The production of clean rice per acre varies between 568 to 809 lb. compared to 3,234 lb. in Spain, 3,105 lb. in Italy, 2,251 lb. in Japan and 3,062 lb. in Egypt. This low productivity must be attributed among other things to the big gap which still exists between the research laboratories and the cultivators. The Indian Council of Agricultural Research has been trying to equip the Extension Workers as well as all others interested in the crop with authoritative information on different aspects of its cultivation. *Rice in India* is the most comprehensive book in this series of information literature. Its first edition, printed in 1956, has been sold out, which

is a testimony to its importance. I am glad the book is being reprinted after careful revision of the original material, and hope that it would serve the mounting need for correct factual information on this important crop.

PANJABRAO S. DESHMUKH
MINISTER FOR AGRICULTURE
GOVERNMENT OF INDIA

New Delhi
August 18, 1959

PREFACE

The first edition of *Rice in India,* published in November, 1956, on the occasion of the Fifth Session of the International Rice Commission held in India, was exhausted in about a year's time. This is an ample testimony to the usefulness of the Monograph. The second edition, which is being brought out in response to the demand for it from different parts of the world, incorporates all the available scientific information on the crop and also includes the results of research reported since the publication of the first edition. It is, therefore, hoped that the book in its revised form will prove to be of still greater interest and utility to scientific workers as well as to others interested in various aspects of rice production.

Rice is the principal food of nearly half the world's population. It is predominantly an Asian crop, 95 per cent. of it being produced and consumed in the South-East Asian countries extending from the Indo-Pakistan sub-continent to Japan.

The Indian Union contains a third of the total rice area, and its output of clean rice amounts to about 31 per cent. of the world production. The crop is grown in almost all parts of the country. But its cultivation is concentrated mostly in Assam, West Bengal, Bihar, Madhya Pradesh, Orissa, Andhra Pradesh, Madras, Mysore, Maharashtra, Gujerat and Uttar Pradesh, which together account for about 95 per cent. of the country's production. However, in spite of its great antiquity and wide cultivation, the average yield in India is one of the lowest in the world. The main reason for this is to be found in the inadequacy of irrigation facilities and poor knowledge about the scientific methods of production, and control of pests and diseases. The Extension agency under the National Extension Service is now making concerted efforts for the dissemination of the results of research on a countrywide scale. The need for an authoritative monograph encompassing every important aspect of the production, processing and marketing of this most valuable foodgrain cannot, therefore, be over-emphasized.

The authors of *Rice in India* deserve to be congratulated for the admirable work they have done. They have been ably assisted by the Research Officers of the Central Rice Research Institute, Cuttack in the revision of the Agricultural Section of the monograph. The contribution of Dr. D. Ganguly particularly deserves mention.

M. S. RANDHAWA, D.Sc., I.C.S.

VICE-PRESIDENT
INDIAN COUNCIL OF AGRICULTURAL RESEARCH

New Delhi
May 30, 1960

PREFACE TO FIRST EDITION

The National Rice Commission of India, at its inaugural session held at New Delhi in April 1956, decided at the instance of Dr. M.S. Randhawa, I.C.S., Vice-President, Indian Council of Agricultural Research, that a monograph dealing with the rice crop in India should be published on the occasion of the Fifth Session of the International Rice Commission, scheduled to be held in India at Calcutta from 12th to 19th November, 1956. It was further decided that in order to present a comprehensive account of the rice crop in India to the delegates of the International Rice Commission Session, the Monograph should have a wide scope and cover all aspects of the work done in the fields of Agriculture, Marketing and Technology of rice. With this view, a Monograph Committee, comprising Shri R.L.M. Ghose, Director, Central Rice Research Institute, Cuttack, Dr. M.B. Ghatge, Agricultural Marketing Adviser to the Government of India and Dr. V. Subrahmanyan, Director, Central Food Technological Research Institute, Mysore, was constituted to compile and rewrite in a suitable form the Agricultural, Marketing and Technological sections of the Monograph, respectively.

The rice crop is cultivated in almost all the states in the country. India has a long record of research on the crop, and in some of the States, rice research, particularly breeding and agronomic, started over four decades ago. The State Departments of Agriculture were invited to send to the Committee an account of the rice crop in their respective States, and it is a pleasure to acknowledge with thanks the information supplied for the Monograph by Shri B.N. Duara from Assam, Shri N.H.V. Krishnamurty from Andhra Pradesh, Dr. S. Ramanujam and Dr. S.K. Roy from Bihar, Dr. T.G. Shirname, Dr. S. Solomon, Shri P.Y. Shendge and Shri V.V. Deodhar from Bombay, Shri B.S. Varadarajan from Coorg, Shri M.S. Pawar, Dr. A.D. Desai, Dr. M. Quadiruddin Khan, Dr. S. Vaheeduddin and Shri M. Fareeduddin from Hyderabad, Shri M. Bhavanishankar Rao and Shri P.C. Sahadevan from Madras, Shri M. Kanti Raj from Manipur, Shri B.B. Dave from Madhya Pradesh, Dr. G.V. Chalam, Dr. B.N. Sahoo, Shri N.N. Mohanty and Shri G.C. Sen Gupta from Orissa, Dr. L.S. Negi from the Punjab, Shri Z.H. Patel from Saurashtra, Shri M.C. Cherian and M. Janardhan Nair from Travancore-Cochin, Dr. S.B. Singh and Dr. B.N. Lal from Uttar Pradesh, Shri Sultan Singh from Vindhya Pradesh and Dr. H.K. Nandi from West Bengal.

Shri S.C. Roy, Agricultural Extension Commissioner, very kindly arranged to have notes written on the Japanese method of rice cultivation, procurement and distribution of fertilizers, the Plant Protection Organisation in India and implements and machines for rice cultivation. The information supplied by him and Dr. K.B. Lal, Plant Protection Adviser to the Government of India and Shri D.N. Kherdekar, Agricultural Extension Engineer on these subjects is gratefully acknowledged.

Dr. H.S.R. Desikachar of the Central Food Technological Research Institute, Mysore, has been closely associated in the preparation of the Technological Section of the Monograph and the valuable help and assistance rendered by him is acknowledged with thanks.

Shri G.J. Hiranandani and other officers of the Directorate of Marketing and Inspection have greatly helped and assisted in the preparation of the Marketing Section of the Monograph; the co-operation and assistance received from these officers is gratefully acknowledged.

In compiling the Agricultural Section of the Monograph, *Circular Letters* of Dr. Panjabrao Deshmukh, Union Minister for Agriculture; *Rice Breeding and Genetics* (I.C.A.R. Scientific Monograph No. 19, 1953) and *Factors Affecting Rice Production* (FAO Development paper No. 45, 1954) by Dr. K. Ramiah; *Manuring of Rice in India* (I.C.A.R. Bulletin No. 38, 1952) by Shri R.L. Sethi, Dr. K. Ramiah and Shri T.P. Abraham; *Manual of Rice Diseases* (Commonwealth Mycological Institute, Kew, Surrey, 1950) by Dr. G. Watts Padwick and *Final Report of the All India Soil Survey Scheme* (I.C.A.R. Research Bulletin No. 73, 1953) proved invaluable, and have been freely drawn upon.

I am greatly indebted to Shri S.Y. Padmanabhan, Dr. M.V. Vachhani, Shri P. Israel, Shri S. Sampath, Dr. C.T. Abichandani, Dr. S. Govindaswami, Shri W.T. Butany, Shri M.S. Pillai, Shri D. Ganguly, Shri M.P. Jha and others on the Research Staff of the Central Rice Research Institute, Cuttack, for their help, co-operation and hard work which made it possible to prepare the Agricultural Section of the Monograph in the short time at our disposal. Special mention must be made of the Ministerial Staff of the Institute who willingly shouldered the heavy typing responsibility connected with this work.

Cuttack
August 15, 1956

R.L.M. GHOSE
CENTRAL RICE RESEARCH INSTITUTE

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CHAPTER I

HISTORY, AREA AND PRODUCTION

Rice (*Oryza sativa* L.) is the most important food crop of India as also of Asia. It is of great antiquity, and therefore, fixing the period of its origin or introduction in different countries of Asia presents difficulties. De Candolle (1886) cites the translation of a Chinese text wherein it is recorded that the crop was being grown in China in about 2800 B.C. ; this is the earliest mention of rice in any writing. In India, rice has been cultivated since ancient times. This is supported by archaeological evidences and by the many references made to rice in ancient Hindu scriptures and literature. Carbonised paddy grains were found in the excavations at Hasthinapur (Uttar Pradesh) at a site dated between 1000-750 B.C. (Chowdhury and Ghosh, 1953). This is the oldest rice specimen yet known in the world. The oldest literary record of the Hindus is the *Rig Veda*, held to be of a period not later than 1500 B.C. Though reference has been made in this book to crops and cultivation, the rice crop is not specifically mentioned. However, in the subsequent literary and religious works, there are numerous references to rice and rice cultivation. In *Susrutha Samhita*, an Ayurvedic medical compilation dated *circa* 1000 B.C., the differences among rices existing then in India are recognised, and the rices are separated into groups based upon their duration, water requirements and nutritional value. After Alexander's invasion of India in 320 B.C., the Greeks learnt of this crop, and Greek writers mentioned it as a crop indigenous to India, from where it had spread to the Euphrates Valley (Watt. 1892). The Greek term for rice is *Oruza*, and it is possible that this was derived from *Arruzz* (*Al-ruzz*) of Arabic and *arsi* of the Dravidian languages. The Greeks learnt of this cereal from the Arab traders who visited the West Coast of India, even prior to Alexander's invasion. It is possible that the Dravidian people utilised rice as a crop before the Aryan civilisation and the development of the Sanskrit language. Rice cultivation probably spread to north India from the south.

Rice, though principally a tropical crop requiring high temperature and humidity for its growth, is cultivated both in the tropical and sub-tropical zones extending from 40° S to 45°N latitude. However, most of the rice area lies between Equator and 40°N latitude and between 70° to 140°E longitude. It occupies 256 million acres, with an average annual production of about 116 million tons of clean rice. It is predominantly an Asian crop, 93 per cent. of rice being produced and consumed in South Asian countries, extending from the Indo-Pakistan sub-continent to Japan. The distribution, production and average yield in the various continents of the world, and the principal rice-growing countries are given in Table 1 and 2.

In spite of the large acreage under rice in Asia, most of the countries of the continent are deficient in rice. While Burma, Indo-China and Thailand have an exportable surplus, and China, Indonesia and Taiwan are self-

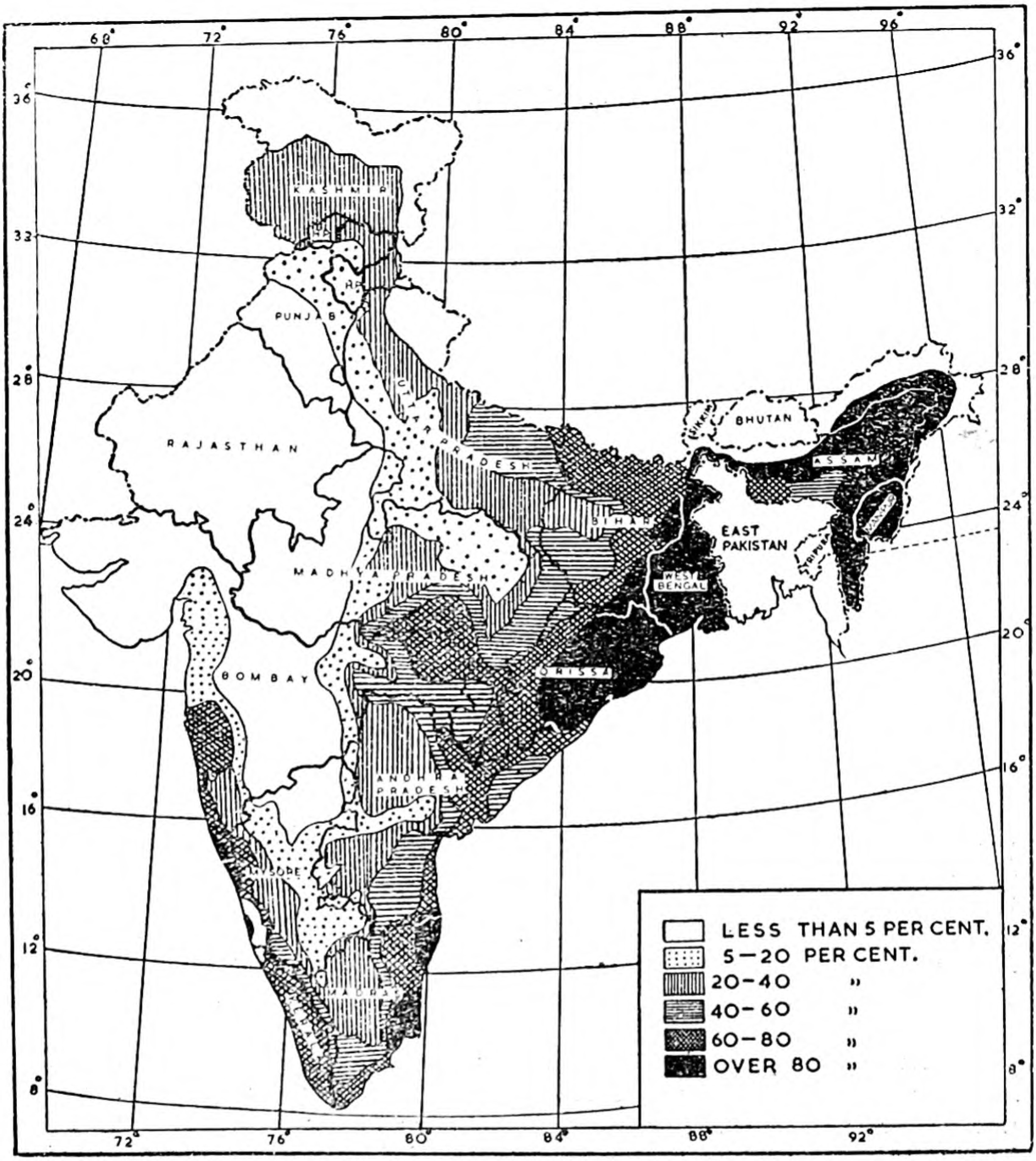


FIG. 1. Distribution of rice area in India

TABLE 1. ACREAGE AND PRODUCTION OF RICE IN THE DIFFERENT CONTINENTS (AVERAGE OF 1950-55)*

Continent	Area		Production of clean rice**	
	Million acres	Percentage	Million tons	Percentage
Asia	238.01	93.04	108.43	92.85
America	9.75	3.81	4.89	4.19
Africa	7.07	2.76	2.36	2.02
Europe	0.89	0.35	1.02	0.87
Oceania	0.11	0.04	0.08	0.07
Total	255.83	100.00	116.78	100.00

TABLE 2. ACREAGE, PRODUCTION AND YIELD OF RICE IN PRINCIPAL RICE GROWING COUNTRIES (AVERAGE OF 1950-55)*

Country	Area in million acres	Production of clean rice in million tons	Yield of clean** rice in lb. per acre
India @	75.43	24.33	723
China	59.20	39.55	1496
Pakistan	23.23	8.33	803
Indonesia	15.93	6.86	965
Indo-china	15.78	5.51	782
Thailand	13.15	4.55	775
Burma	10.78	4.14	860
Japan	7.42	7.50	2264
Philippines	6.26	1.97	705
Brazil	5.36	2.14	894
Nepal	3.25	0.73	503
U.S.A.	3.08	1.93	1418
Korea	2.55	1.95	1713
Taiwan	1.91	1.36	1595
Madagascar	1.70	0.65	856
Ceylon	1.06	0.41	866
Malaya	0.84	0.43	1147
Egypt	0.54	0.55	2281
Italy	0.41	0.56	3059
Spain	0.16	0.19	2660
Argentina	0.14	0.12	1920
Others	7.65	3.02	—
Total	255.83	116.78	

* Adapted from the *International Rice Year Book* (1957), U.S.A.

** Clean rice has been calculated as 2/3rd of rough rice or paddy. @ Average acreage and production in India for the years 1951-56 is 75.46 million acres and 24.26 million tons respectively.

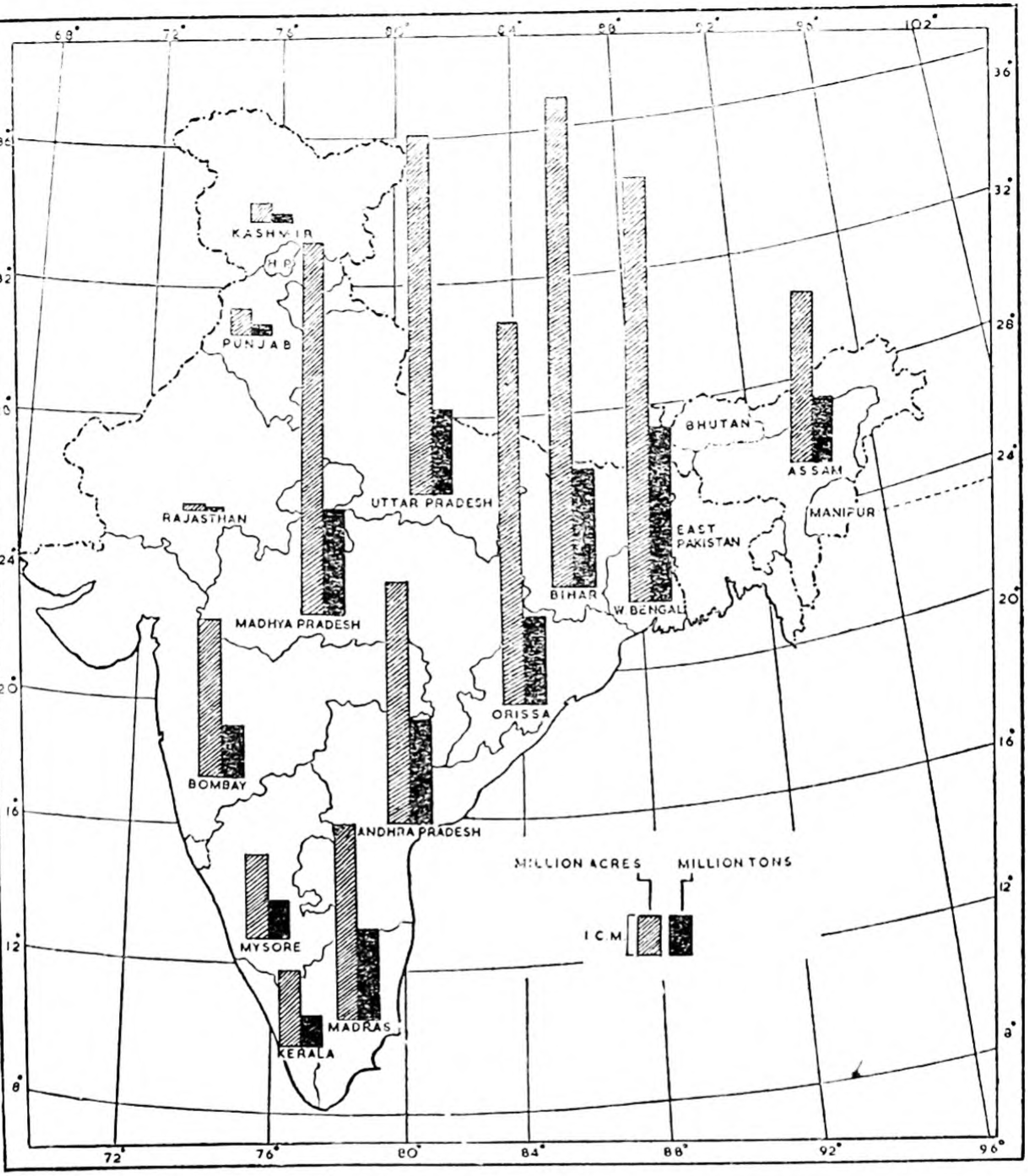


FIG. 2. Rice acreage and production in India

sufficient in their rice requirements, the rest of the countries are deficient, and have to import rice to feed their people.

India is the largest rice-growing country in the world, cultivating about 75 million acres annually, which is about a third of the world acreage under rice. The production of clean rice is 23 million tons. Rice is the most important crop of the country, covering more than 30 per cent. of the total annual cultivated area, and

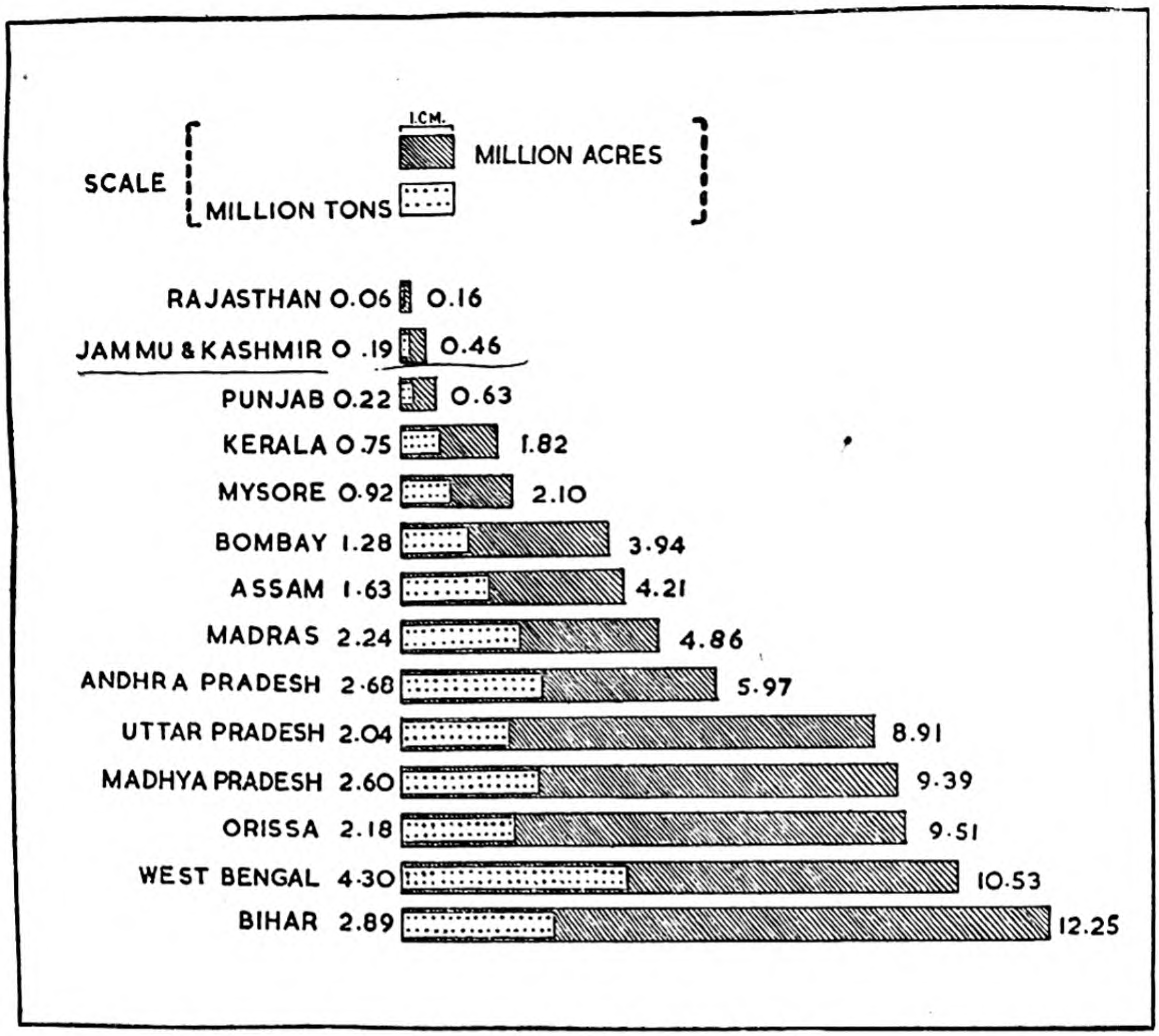


FIG. 3. Comparison of rice production and area in different states

not only forms the mainstay of the diet of the majority of the people, but also bears a large influence on their life and economic condition.

Rice is grown in almost all the States of India, but its cultivation is mostly concentrated in the river valleys, deltas and low-lying coastal areas of north-eastern and southern India, in the States of Andhra Pradesh, Assam, Bihar, Bombay, Kerala, Madhya Pradesh, Madras, Mysore, Orissa, Uttar Pradesh and West Bengal, which together contribute about 97 per cent. of the country's rice production (Fig. 1 & 2). The acreage, production and average yield in the different States are given in Table 3.

India's annual requirement of rice exceeds her production, and the deficit is met by imports. Efforts are being made to increase the production by providing an assured supply of water and adopting intensive methods of cultivation.

TABLE 3. ACREAGE, PRODUCTION AND YIELD OF RICE IN DIFFERENT STATES OF INDIA (AVERAGE OF 1951-56)*

State	Area		Production of clean rice*		Average** yield of clean rice in lb. per acre
	Million acres	Percentage of total	Million tons	Percentage of total	
Bihar ..	12.254	16.24	2.888	11.91	528
West Bengal ..	10.526	13.95	4.298	17.72	915
Orissa ..	9.505	12.59	2.184	9.00	514
Madhya Pradesh ..	9.395	12.45	2.598	10.71	619
Uttar Pradesh ..	8.909	11.81	2.044	8.43	514
Andhra Pradesh ..	5.973	7.92	2.679	11.04	1005
Madras ..	4.860	6.44	2.244	9.25	1034
Assam ..	4.214	5.58	1.627	6.71	865
Bombay ..	3.939	5.22	1.278	5.27	727
Mysore ..	2.104	2.79	0.919	3.79	978
Kerala ..	1.824	2.42	0.747	3.08	917
Punjab ..	0.632	0.84	0.223	0.92	790
Kashmir ..	0.456	0.60	0.194	0.79	953
Tripura ..	0.398	0.53	0.138	0.57	777
Manipur ..	0.198	0.26	0.105	0.43	1188
Rajasthan ..	0.158	0.21	0.059	0.24	836
Himachal Pradesh ..	0.110	0.14	0.031	0.13	631
Andaman and Nicobar ..	0.007	0.01	0.002	0.01	640
Total ..	75.462	100.00	24.258	100.00	

* Adapted from the *Agricultural Situation in India*, October, 1956.

** Clean rice has been calculated as 2/3rds of paddy.

CHAPTER 2

BOTANY, ORIGIN AND VARIETIES

Rice belongs to the genus *Oryza* of the sub-tribe *Oryzineae* in the family *Gramineae*. The genus *Oryza* includes 24 accepted species, of which 22 are wild and two, *O. sativa* and *O. glaberrima*, are cultivated. All the rice varieties of Asia, Europe and America belong to the species *O. sativa*, while many of the cultivated varieties of West Africa belong to the species *O. glaberrima*. All the species are hygrophilous and the genus is distributed in the moist tropics.

It was Watt (1891) who initiated botanical studies on rice in India. With the gradual establishment of agricultural research stations in the different States, these studies have been extended. Ramanujam (1938), Parthasarathy (1938a) and Phatak (1940) studied the cytology of wild species of *Oryza*. Chatterjee (1948) made a critical study of the taxonomy and distribution of the genus. By identifying the synonyms amongst the recorded species of *Oryza*, he concluded that there were only 22 valid species from amongst the 68 specific names listed. Subsequently, two new species, *O. ubanghensis* (Chevalier, 1951) and *O. angustifolia* (Hubbard, 1950), were found in tropical Africa, bringing the total of accepted species to 24. However, Krishnaswamy and Chandrasekharan (1957) have collected and described a wild tetraploid rice from Kerala State, which according to them is a new species. A living collection of species of *Oryza* is being built up at the Central Rice Research Institute, Cuttack, for the study of their cytology and inter-relationships. The natural distribution and somatic chromosome numbers of the species of *Oryza* are given in Table 4.

It will be seen from Table 4 that the maximum number of species, i.e. 10, is found in Africa. In India, five wild species, *O. coarctata*, *O. granulata*, *O. officinalis*, *O. perennis* and *O. sativa* var. *fatua* are found, of which *O. coarctata* is probably endemic.

Among the species of which chromosome numbers are known, six are tetraploids, but none of them is of economic importance. In morphological characters and ecological adaptations, the species show a wide range of variation. In the collection of wild rices available at the Central Rice Research Institute, plant height in *O. brachyantha* is 1 to 2 feet and as much as 6 to 8 feet in *O. alta*. The width of the leaf in *O. brachyantha* is only 3 to 5 mm., while it is 30 to 50 mm. in *O. latifolia*, with corresponding variation in length of the leaf. Regarding the number of spikelets per panicle, *O. granulata* has 8 to 15, while *O. eichingeri* has as many as 300 to 500. *O. minuta* has the smallest grain, while *O. breviligulata* has the largest, approaching the weight and size of the cultivated rice. The normal number of anthers in the genus is six, but in *O. brachyantha* spikelets with four and five anthers are also found, and in *O. ridleyi*, spikelets with rudimentary anthers occur. There is also considerable variability in subterranean stem development. *O. perennis* has thick spreading rhizomes; in *O. coaractata* the rhizomes are slender and spreading, while in *O. granulata* they are compact and small in size. In respect of ecological adaptations,

TABLE 4. NATURAL DISTRIBUTION AND CHROMOSOME NUMBERS OF THE SPECIES OF *Oryza*

Name	2n	Distribution
O. sativa Linn.	24	Cultivated in all the continents
O. glaberrima Steud.	24	Cultivated in West Africa
O. perennis Moench.	24	Asia, Africa, America
O. brachyantha A. Cheval.	24	Tropical Africa
O. breviligulata A. Cheval.	24	,, ,,
O. eichingeri Peter	48	,, ,,
O. stapfii Roschev.	not known	,, ,,
O. ubanghensis A. Cheval.	,, ,,	,, ,,
O. punctata Kotschy.	,, ,,	,, ,,
O. tisseranti A. Cheval.	,, ,,	,, ,,
O. angustifolia Hubbard	,, ,,	,, ,,
O. perrieri A. Camus	,, ,,	Madagascar
O. sativa Linn. var. *fatua* Prain	24	India and South-East Asia
O. officinalis Wall.	24	,, ,, ,, ,, ,,
O. granulata Nees et Arn.	24	,, ,, ,, ,, ,,
O. coarctata Roxb.	48	India
O. meyeriana Zoll et mor.	not known	South-East Asia
O. ridleyi Hook.	48	,, ,, ,,
O. minuta Presl.	48	,, ,, ,,
O. schlecteri Pilger.	not known	New Guinea
O. australiensis Domin.	24	Australia
O. latifolia Desv.	48	South and Central America
O. alta Swallen	48	,, ,, ,, ,,
O. subulata Nees.	not known	South America
O. grandiglumis Prodoehl.	,, ,,	,, ,,

O. granulata and *O. ridleyi* are shade-loving plants, while *O. minuta* and *O. officinalis* thrive well only in partial shade. One variety of *O. perennis* has floating branched stems and grows in standing water, while *O. australiensis* requires well drained soils for an optimum growth. *O. coarctata* grows in tidal swamps, is adapted to salinity in the soil, and has coriaceous leaves with spiny margins, unlike any other species of *Oryza*.

One topic of great interest in the inter-relationships of species in the genus is the origin of cultivated rice from wild species. Three species, i.e., *O. sativa* var. *fatua*, *O. perennis*, and *O. breviligulata* are widely recognised as being closely related to cultivated rice. *O. sativa* var. *fatua*, the common wild rice of India, is polymorphic. It occurs as a weed in rice fields and is a menace to rice cultivation in Kerala, Madhya Pradesh and the Punjab. This wild rice closely resembles the cultivated rice in many respects, and its distribution in South-East Asia coincides with the area of the most ancient cultivation of rice. The *fatua* types cross freely with the cultivated rices, giving fertile hybrids. It is considered that this wild rice is the immediate progenitor of cultivated rices, and it is probable that *O. sativa* has evolved from these wild rices by mutation and selection. The grains of wild rices shatter easily and are difficult to harvest. However, due to religious sentiment favouring this particular rice, the grains are being gathered even today in Andhra Pradesh, Madhya Pradesh and Orissa. It is significant that in ancient times the wild rice (*Neevara* in Sanskrit) was preferred for certain religious occasions. The transition from collecting wild rice to cultivating rice was a natural step to be taken by the agriculturist. Since this or similar wild rices are abundant in India and South-East Asia, it is thought that rice cultivation originated in India, Burma or Indo-China (Ramiah and Ghose 1951 ; Sampath and Rao 1951 ; and Chatterjee 1951) and from the centre of its origin it spread to other countries.

The taxonomy of the wild rice commonly termed *fatua* or *spontanea* presents some difficulties. Chatterjee (1948) has suggested that these be given a specific status, *O. fatua* Koen. However, these cross freely with cultivated rice in nature and species delimitation is difficult. Ramiah and Ghose (1951) record that the natural populations of wild rice are highly heterozygous and segregate for types approaching cultivated rices. Sampath and Rao (1951) suggest that the *fatua* rices are of hybrid origin, and that they cannot be given a specific status, as there is neither constant morphological distinction, nor geographical isolation, nor genetic barrier between these wild rices and *O. sativa*. They suggest that this weed population originated by natural crossing between *O. sativa* and *O. perennis*. Varieties of *O. perennis* can be wrongly grouped with the *fatuas*, as even the Indian Floras do not list this species. However, Ramiah and Ghose (*l.c.*) have identified one of the wild rices common in Orissa, having a short rhizome, branched floating stem and perennial habit as *O. perennis*. The rhizome and perennial habit are important diagnostic features of *O. perennis*. Wild rices with these characters have been recorded from different areas in Asia. Mitra and Ganguli (1932 a) have observed the presence of rhizome in a wild rice type from Assam. Beale (1927), Backer (1946) and Oka (1956) have recorded the presence of perennial wild rice in Burma, Indonesia and Formosa respectively. This species is polymorphic and geographical varieties are known. The relationship of this species to the *fatua* types and to cultivated rice is yet to be determined.

It is necessary to postulate an independent origin for *O. glaberrima*, in Sudan or West Africa. Porteres (1946) has discussed the evidence for the origin of *O. glaberrima* from *O. breviligulata* and Sampath and Rao (1951) have suggested *O. perennis* as the putative ancestor. One of the reasons for postulating an independent origin for rice cultivation in West Africa is the absence of evidence that rice cultiva-

tion was at any time introduced from Asia into West Africa or vice versa. If such an introduction has taken place, it would have been only from Egypt, a country suited to grow rice and also one with an ancient civilization. In the tombs and records of ancient Egypt, which go back to 2,000 B.C., there are neither specimens nor any mention of rice. The antiquity of *O. glaberrima* cultivation in Africa is unknown.

Since its origin, the cultivation of rice, *Oryza sativa*, has spread to different countries, and at present is grown in most of the countries where its cultivation is practicable. Grist (1953) gives instances of its spread in ancient times. In Ceylon, rice was probably cultivated as early as 500 B.C., as shown by the complex irrigation constructions of that period. Malayan migrants to Indonesia in prehistoric times are considered to have introduced rice cultivation into that country. Immigrants from South China to the Philippines before the first millennium B.C., are believed to have brought rice with them and to have built the vast terrace systems for rice cultivation. Matsuo (1955) is of opinion that rice was introduced from China into Japan in the first century B.C. Malayans are believed to have introduced rice cultivation into Madagascar at an early period.

From India, rice spread northward and westward. Excavations in ancient Khotan (Turkestan) have yielded specimens of rice estimated to be from the fifth century B.C. (Aurel Stein, 1907). The introduction of rice into Persia was at an unknown period. After the spread of Islam, Arabs started its cultivation in Egypt, and the Moors in Spain. From Spain it was introduced into Italy in the fifteenth century. The Portuguese introduced rice into Brazil, and the Spaniards into Central America. The first rice cultivation in the U.S.A. was started in South Carolina in 1694, with seeds obtained from Madagascar. Subsequent introductions were made from Japan. In modern times, exchange and introduction of rice varieties are being conducted on a vast scale.

Since its origin, rice has undergone genetic diversification, resulting in thousands of varieties being grown all over the world. In India alone, 4,000 varieties are reported to have been recorded (Ramiah 1953 a). As rice is predominantly self-fertilized, the varieties are homozygous, and the differences between them are genic. Over 300 genes have been identified in rice and hence the potential number of varieties is enormous. The differences between varieties are in the morphological as well as physiological characters, the former being a striking feature of any large varietal collection. The physiological characters are of economic importance, as they control the yielding capacity of the plant. The genetic variability is attributable to mutation, hybridization, selection and the great diversity in the growing conditions of the crop.

The *sativa* rice varieties of the world are commonly grouped into three sub-species, namely, *indica*, *japonica* and *javanica*. The distinctions between the sub-species are not absolute, but are based on morphological characters and also in adaptations to temperature and photoperiod conditions prevailing in different rice regions of the world. The hybrids between plants of different sub-species show varying degrees of sterility.

The *javanica* or *bulu* sub-species includes a small number of varieties adapted to low latitudes. These are found mainly in Indonesia. However, according to

Ramiah (1955), a few varieties of this sub-species apparently occur also in the Philippines, India and Ceylon, and under the name of *Vary lava* in Madagascar. Ramiah (*l.c.*) is also of the opinion that just as *japonica* arose from *indica* in China, the *bulu* group might have developed independently from *indica* in Java, and was introduced into other regions from there. The *javanicas* are characterised by a stiff straw, long panicle with awned grains, sparse tillering habit, long duration and low sensitivity to differences in natural day-length.

The *japonica* varieties were developed in Japan and are adapted for cultivation in the sub-tropical and warm temperate regions. In addition to their adaptation to particular ecological conditions, the *japonica* varieties mostly have oval and round grains, the spikelets show distinctive pubescence near the apex and the panicles are compact and dense. The range of variation in morphological characters is apparently smaller than in the *indica* sub-species.

All the varieties not included in the *javanica* or *japonica* sub-species are grouped together as *indicas* and are cultivated all over tropical Asia. In the *indica* group, the range of variation is very large. Rice grown in India belongs to the *indica* sub-species, and has been intensively cultivated over a long period under conditions favourable to the development of local forms, with the result that the crop is now a vast complex of forms showing large variations in morphological and physiological characters. Among the physiological characters, the two important ones are duration and adaptation to particular seasons. In duration, the varieties vary from about 80 days to over 200 days. Varieties adapted to different seasons are prevalent, and rice is grown throughout the year in some part or the other in India. As regards water requirements, at one extreme are the varieties which are grown under upland conditions, while at the other are the deep-water rices of Assam and West Bengal which grow in 15 to 20 feet of water. Varieties resistant to salinity are found in different States. The cultivation of this crop extends from sea level to high altitudes of 4,000 to 5,000 feet as in Kashmir, and different varieties are grown for diffrent altitudes and temperatures. In morphological characters, the occurrence and distribution of anthocyanin pigmentation in the plant organs are very variable. The plants range from fully green in all parts, pigmentation present in only one, two or more parts to fully pigmented in all parts. In height, the plant (excluding dwarfs) varies from about 2½ feet to about 20 feet. In the number of fertile tillers, the variation may be from 2 to 3 to 25 to 30 tillers per plant. The panicle size ranges from 13 to 42 cm. In grain dimensions, the length varies from 5.3 to 11.8 mm., and breadth from 1.9 to 3.1 mm. Exceptional panicle types like cluster, where spikelets occur on whorls, are found in several regions. In Kernel types, red rices are grown in all the States, and are preferred in Kerala. Fine, scented rices are grown all over India. Glutinous types are grown on a small scale in all the rice areas for special purposes.

The origin of varieties cannot be localised to any particular area in India, and it is probable that independent development has taken place in all the rice-growing regions. Some regions are, however, markedly richer in rice varieties. A botanical survey of rice varieties in Koraput District of Orissa is now being conducted by the Central Rice Research Institute under a project sponsored by the Indian Council of Agricultural Research. This area is considered to be a secondary

centre of origin of rice. Uptil now, in this survey, 1,050 samples of rice varieties have been collected. The grain types in this collection varied from very coarse to fine grain and included rounded pubescent *japonica* type of grains. Rice varieties with clustered type of panicle, with long sterile lemma and with glutinous endosperm have been collected. A variety, resembling the West African species, *O. glaberrima*, has also been found. This area is also rich in varieties of the wild species, *O. perennis* and *O. sativa* var. *fatua*.

Classification has been made of rice varieties of Assam (Mitra and Ganguli, 1932b), Bihar (Kashiram and Saravayya, 1934), Bengal (Hector and Sharangapani, 1934) and Uttar Pradesh (Sethi and Saxena, 1930). These classifications are based primarily on morphological characters, and there are difficulties in applying a uniform system to all the *indica* varieties. Any system of classification has to be of use in breeding and agriculture, and therefore, field characters are important. One such character, duration, is largely influenced by the time of planting, and the natural photoperiod during the growth period. Ramiah (1953a), discussing this problem, has pointed out that varietal characters of practical importance are the life period of the crop, the agricultural season in which it is grown, and the grain characters, including the colour of the kernel. Ramiah (*l.c.*) has pointed out that even a broad classification is difficult to apply to any large collection, where there will be inter-grading of characters, and that familiarity with the types and an accurate description of their characters constitute a practical method of identifying the varieties. To facilitate description of genetic characters in rice, Hutchinson and Ramiah (1938) have prepared schedules, charts and plates, and a general adoption of these methods of presenting the data is desirable.

The commercial classification of grain is also a necessity and is independent of botanical classification. Vachhani *et al.* (1952) have discussed the problem as it applied to the internal market in India and suggested that both qualitative and quantitative characters should be used. Qualitative characters pertain to the colour, scent and texture of the hulled rice. Quantitative characters are the length, breadth, length/breadth ratio and the 1,000 grain volume of the rice in husk. They found that seven physical grades could be established with these measurements, and that most of the improved strains of the States in India can be fitted into these seven groups.

CHAPTER 3

CLIMATE AND SEASON

Rice cultivation in India extends from 8° to 35° N latitude, and the crop is grown under widely varying conditions of rainfall, altitude and climate. There are rices grown at sea level in the river deltas, in areas even below sea level with protective embankments as in some parts of Kerala State, in 15 to 20 feet of water as the deep-water rice in the States of Assam and West Bengal, and at altitudes of 3,000 to 5,000 feet and even more as in Kashmir and the slopes of the Himalayas. The rice crop requires high temperature and high humidity, with abundance of water during its life period. Therefore, weather conditions such as rainfall and its distribution, temperature and day-length have a marked influence on the growth as well as on the yield of rice, and these factors determine where and to what extent the crop can be grown.

Rainfall. Monsoons, which affect the climatic conditions of most of the South-East Asian countries, occur in India with a well marked seasonal rhythm, involving concentration of precipitation, a warm humid weather coinciding with the rice-growing season, and a relatively dry season at the time when the rice matures. During the months of June-October, the South-west Monsoon brings abundant rainfall. One arm of the monsoon from the Arabian Sea strikes the Western Ghats of the Peninsula, causing 60 to 200 inches of rain in the West Coast areas, and 20 to 40 inches in the eastern plateau. Another arm of the monsoon from the Bay of Bengal strikes the North-east Coast, and moves upwards to the right and the left. Thus the South-west Monsoon brings rain to all parts of the country, and most of the rivers in the country, which are the sources of irrigation water, depend on the rainfall received from the monsoon. Variations in the arrival, duration, distribution and intensity of the South-west Monsoon have a large influence on the growing of the rice crop, as the bulk of the crop in the country is entirely dependent on the rainfall. The rainfall is the highest in the north-eastern region, where a precipitation of 200 inches or more per year is recorded. Going west and northwards along the northern plain, the rainfall rapidly decreases, but much of this plain is well-watered by the rivers flowing from the Himalayas. In the eastern area, the rainfall is about 50 to 60 inches, while further south in the plateau region of the Peninsula, the rainfall gradually decreases. On the West Coast, the average rainfall ranges from 60 to 120 inches per year.

During the winter months, the direction of the monsoon is reversed. The North-east Monsoon brings rain to the East Coast of Andhra Pradesh and the southern districts of Madras State during the months of October-January.

Rice culture follows the rainfall line, as will be seen from Fig. 1 and 4. In the north-eastern region, comprising Assam, West Bengal, Orissa and south Bihar, where the rainfall is high, rice is a dominant crop, occupying more than 80 per cent. of the cultivated area. Going further south through the plateau region of the Peninsula, the rainfall decreases, and the rice crop is grown to the extent of

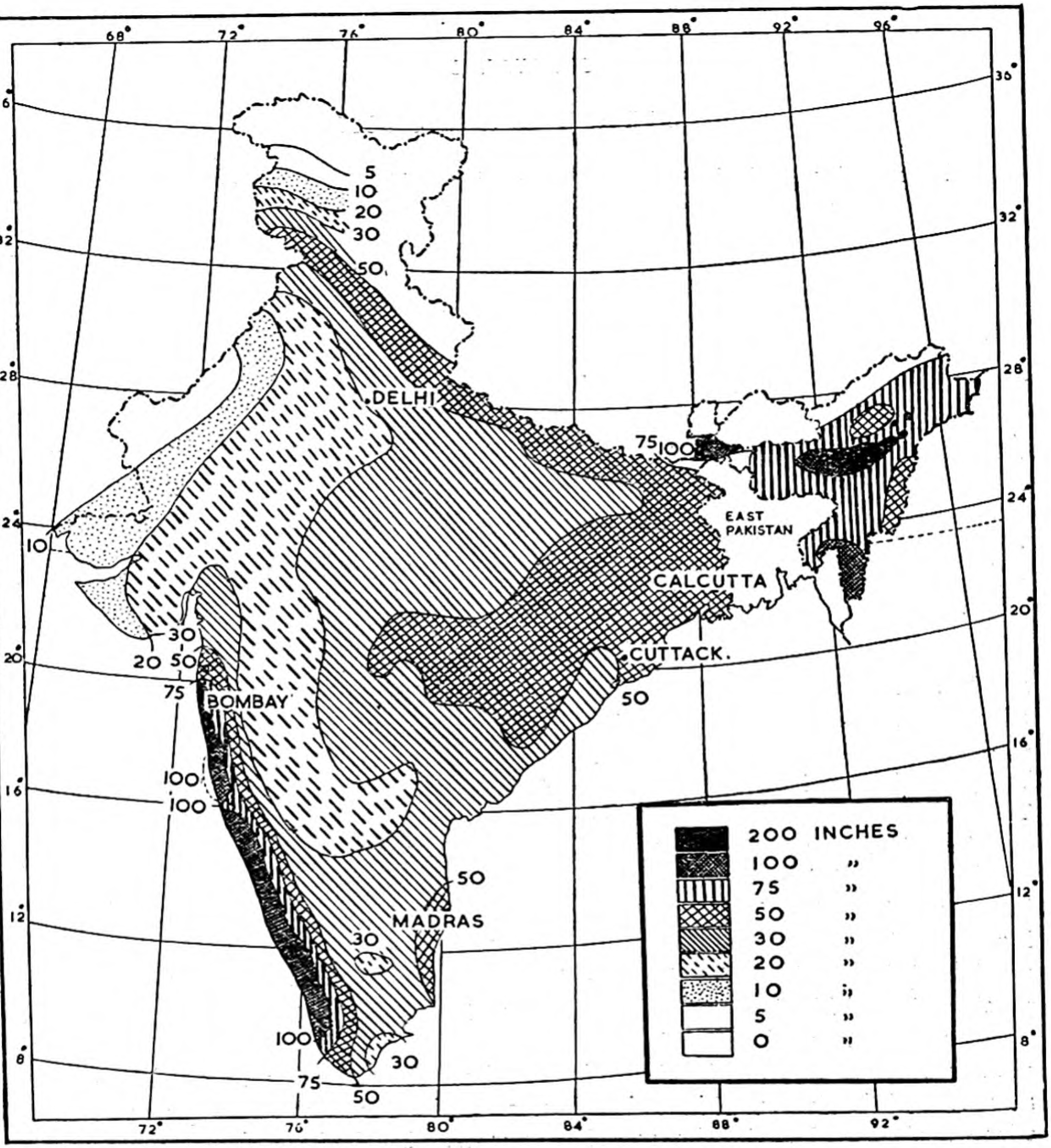


Fig. 4. Distribution of rainfall

30 to 40 per cent. of the cultivated area, being concentrated in the east and west coastal areas of Andhra Pradesh, Madras and Kerala States. In northern and central India, rice is grown wherever rainfall conditions are favourable.

Temperature and Day-length. The rice crop needs a hot and humid climate. The average temperature required throughout the life period of the crop ranges from 21° to 35°C. It seldom succeeds where the temperature during the growing season is less than 25°C. In the eastern region and the Peninsular India, the mean temperatures throughout the year are favourable for rice cultivation, and two or even three crops of rice are taken during the year. In northern and western India, where the winter temperature is low, only one crop of rice during the months of May-November is possible.

The total heat units or thermal units required to mature a rice crop (summation of the daily mean temperatures above the base of 0°C throughout the growing period) varies with the duration of the variety and location. In India, a variety of 105 days duration, on the average, requires about 3,000°C, while a late variety of five months duration requires 4,400°C to 6,600°C.

In India, the difference in the length of the day and night ranges between one to two hours during the rice-growing season. Photoperiodically, rice is a short-day plant. However, there are varieties which are non-sensitive to photo-periodic conditions (day-length) and complete their life cycle satisfactorily, irrespective of the day-length. Based on the response to day-length, rice varieties are classified into sensitive and non-sensitive groups. From experience it has been found that the long duration varieties are usually sensitive, and have to be grown only during a specific season, while the short duration varieties are non-sensitive, can be grown in any part of the year, and are commonly cultivated during the autumn and summer seasons.

Latitude. As already mentioned, rice cultivation in India extends from 8° to 35° N latitude. Rice yields obtained within this area do not appear to bear any relationship to the latitude, as will be seen from Appendix I. The rice areas in the States of Madras, Kerala and Andhra Pradesh, situated between 8° to 20° N latitude, and the States of the Punjab and Kashmir, situated above 30° N latitude, record higher yield, while the rice areas in the States of Uttar Pradesh, Bihar and Madhya Pradesh, situated between 20° to 30° N latitude, record lower yields. Further, it will be seen that rice yields in Assam and West Bengal are much higher than those in Bihar and Uttar Pradesh, though all these States are situated practically within the same range of latitude. The differences in yields obtained in the States at various latitudes can be attributed to the water conditions prevailing in these areas.

Altitude. Though rice is grown in India on higher altitudes of 3,000 to 5,000 feet above sea level, the bulk of the crop is grown in the river valleys and deltas, where plentiful supply of water is available. It has been observed that at higher altitudes, as in Kashmir (3,000 to 5,000 ft.) and Coorg and other parts of Mysore State (2,500 to 3,000 ft.) , the average yields of rice obtained are higher than in the plains. Ramiah (1954) observed that in South India, the same variety of rice belonging to the non-sensitive group planted in two centres on the same latitude but with different altitudes differed in its duration and productivity. Rice

grown at 3,000 feet elevation took two weeks longer to mature, and yielded 10 per cent. more than that planted at sea level. In Assam on the other hand, higher yields have been reported from the plains than on higher elevations(2,000 ft.). It is not definitely known whether differences in altitude alone or other factors like temperature and day-length combined with altitude affect the yield.

Season. Rice-growing seasons vary in different parts of India, depending upon the rainfall and other local climatic conditions. However, in greater part of India, the rice crop can be broadly classified into three groups according to the season when it is harvested, *viz.*, *aus* or autumn rice, *aman* or winter rice and *boro* or spring and summer rice. These crops, however, may be termed variously in different parts of the country, and have slight variations in the sowing and harvesting times. The most important crop of the country is the *aman* crop, the growing season of which coincides with the South-west Monsoon. It is sown during June-July and harvested in November-December. The crop is taken in low lands and long duration varieties of 140 to 160 days are grown.

The *aus* crop is sown in May-June and harvested in September-October. The crop is grown in uplands and short duration varieties of 90 to 110 days are used. The *boro* crop is sown in December-January and harvested in March-April, and short duration varieties are used.

It may be mentioned that over large areas in the country only one crop of rice a year is grown, but in certain areas two or even three crops a year are grown on the same land.

RICE REGIONS

The rice areas in the country can be broadly grouped into the following five regions according to the rice-cropping season.

1. North-eastern Region. This area, which comprises Assam, West Bengal, South Bihar and Orissa, grows rice in the basins of the Brahmaputra, Ganga and Mahanadi rivers, and has the highest intensity of rice cultivation in the country. The main rice season is from June-July to November-December, when the most important rice crop of the region, i.e., the winter crop known as *aman* in West Bengal and Bihar, *sali* in Assam and *sarrad* in Orissa, is grown either broadcast or transplated in the low and medium lands.

In the uplands of this region, a short duration crop called *aus* in West Bengal *ahu* in Assam and *beali* in Orissa is sown broadcast in May-June and harvested in September-October. However, in the alluvial soils of West Bengal, the *aus* is usually transplanted in May, and harvested in August-September.

Another crop season in this region extends from November-December to March-April, when a spring or summer rice called *boro* in Bengal and *dalua* in Orissa is grown in low, marshy areas in the margins of natural depressions. The cultivation of the crop usually starts when the flood water recedes. The three crops do not necessarily occupy the same land, although double cropping of rice is practised to a limited extent.

2. Southern Region. This area, comprising the deltaic tracts of the Godavari, Krishna, Cauvery and Tambraparni and the non-deltaic rain-fed areas of Madras, Andhra Pradesh and Kerala also has three rice-growing seasons. Depend-

ing upon water conditions, two to three crops of rice are grown on the same land during the year. Due to varying water conditions in this region, it can be further divided into four distinct zones.

(i) THE SOUTHERN ZONE: It comprises the delta areas of the Cauvery, Vaigai and Tambraparni and has two main seasons, *viz.*, (a) *kuruvai* or *kar* (June-September) corresponding to the *aus* crop season of the north-eastern region, and (b) *thaladi* or *pishanam* (September to February-March). Short or medium-duration varieties are grown in the *kuruvai* or *kar* season as the first crop, followed by a second crop called *thaladi* or *pishanam* of long-duration varieties from September-October to February-March, which receives the benefit of the North-east Monsoon. Both these crops are transplanted. Besides the two main seasons, there is the *samba* season, extending from August to January, when a medium or long duration crop is grown in such of the delta areas as are not double-cropped for want of irrigation facilities. In the tank-fed areas of the zone, if the monsoon is favourable, a first crop of medium duration is taken from June-July to November- December, followed by a second crop called *manavari* (December-February) or *navari* (January-May). However, in the years when the monsoon is not favourable, only the *manavari* or *navari* crop is taken.

(ii) THE WEST COAST ZONE: It has three rice seasons in the year, called *viruppu*, *mundakan* and *punja*. The *viruppu* is the first crop season from April to September, and medium-duration (110-120 days) varieties are grown. The second crop *mundakan* is sown in September-October and is harvested in January-February. The third crop *punja* is cultivated between December-January to March-April, and is mainly an irrigated crop of a short-duration variety of about 100 days.

(iii) THE NORTHERN ZONE: This zone, comprising the deltaic tracts of the Godavari and Krishna, has two clear-cut seasons, *viz.*, (a) *sarva*, June to November-December and (b) *dalua*, December-January to April-May. Unlike the southern zone, a long-duration crop of rice is grown as the first crop, followed by a second crop of a short or medium duration. The second crop-planting starts only by the end of January.

(iv) NON-DELTAIC AREAS: In the non-deltaic areas, especially in the Nellore tract of Andhra Pradesh, the rice season is not well-defined and is dependent on the monsoons. Under favourable rainfall conditions, transplanting commences from the middle of August. However, this condition rarely occurs and planting is usually done much later and continues up to October. Usually, a medium or long duration crop is grown.

3. Central Region. The area comprising Madhya Pradesh, parts of former Hyderabad, now in Andhra Pradesh and Mysore, has its main rice season from June to November-December and second rice season from January to May in some parts.

In most of the rice areas in Madhya Pradesh, only one crop of an early or a medium-duration variety, maturing by the middle of November, is grown mainly as a rainfed crop. Broadcasting is the common practice, but transplanting is adopted in the Wain-Ganga basin, which has assured irrigation facilities.

In the areas of former Hyderabad State, the *abi* crop is grown from May-June to November-December, while a second crop, *tabi*, is grown in January-May.

Generally, medium or late-duration varieties are grown for *abi* and short-duration ones for *tabi.*

In the greater part of Mysore State, there are two seasons for rice. The *haine* crop is raised in June-December, while a summer crop is grown in places with irrigation facilities in January-February to May-June.

4. Western Region. The area comprising the coastal zone of Bombay State and parts of South Kanara district of Mysore State, has only one season from May-June to November-December and a medium or long-duration variety is grown.

5. Northern Region. This area comprising Jammu and Kashmir, the Punjab, Uttar Pradesh and North Bihar, has low winter temperatures, and only a single crop of rice can be grown from May-June to September-October. Short and medium-duration varieties of 110-120 days are usually grown, as the crop should mature before the onset of winter.

Details of climatic conditions, rice growing seasons and cultural practices in the different States are given in appendix I.

CHAPTER 4

CLASSIFICATION OF SOILS

In India rice is grown under diverse soil conditions and over a wide range of soil reaction, ranging from *p*H 4.5 to *p*H 8.0. Large areas under the crop are found along the banks of rivers, as water rather than soil is the more important factor in deciding on the suitability of an area for growing the rice crop.

Though almost all types of soils in the country grow rice, the success achieved, however, varies and depends on availability of water during the growth period, soil management and fertilizer practices. The soils most suited to the cultivation of the crop are heavy soils—clays or clay loams. Such soils, capable of holding water, are found under tank irrigation conditions and river delta areas, and crops on these soils give high yields. The most important groups of soil under which the crop is grown in the country are the alluvial soils, red soils, laterite and lateritic soils, black soils, saline and alkaline soils, and peaty and marshy soils. The characteristics of these soils have been described in the Final Report of the All-India Soil Survey Scheme (I.C.A.R. Bull. No. 73, 1953).

Alluvial Soils. These soils are the most extensive and agriculturally important among the soil groups in India. They include the Indo-Gangetic alluvium and the deltaic alluvium of Peninsular India, and are distributed mainly in the northern, north-western and north-eastern parts of India, including the Punjab, Uttar Pradesh, Bihar, West Bengal, parts of Assam and Orissa, and the coastal and deltaic areas of South India. The soils of the Indo-Gangetic alluvium and deltaic areas are derived mainly from the mountain and hill washes brought down by the great rivers and deposited in the plains below. These soils grow a variety of crops including rice, wheat, sugarcane and cotton. Chemical analysis of these soils has shown that they are low in nitrogen, humus and phosphoric acid, but are generally well supplied with potash and lime. In Uttar Pradesh, West Bengal and Assam, the alluvial soils have been further sub-divided into old and recent alluviums. The old alluvium is red in colour and is deficient in lime, phosphoric acid and humus. The recent alluviums, however, get periodic deposits of fresh silt and are more fertile than the old alluviums.

Red Soils. This group of soils covers the whole of Peninsular India, excepting the area of the Deccan trap and the narrow strip of coastal alluvium. These soils comprise practically the whole of Madras, Mysore, south-east Bombay, the Telangana area of Andhra Pradesh, eastern part of Madhya Pradesh, Orissa and Chota Nagpur areas. In North India, red soils extend into the greater part of the Santhal Parganas of Bihar, Birbhum district of West Bengal, Mirzapur, Jhansi and Hamirpur districts of Uttar Pradesh and the former Baghelkhand Agency of Central India.

These soils are of sedentary formation, and in the lower levels comprise decomposition products washed down by rains. The characteristics of the soils are their

light texture with a porous, friable structure, absence of the lime *kankar* and free calcium carbonate in the profile, and the low soluble salt content, the latter usually not exceeding 0.05 per cent.

The most common form of red soil met with in the country is the sandy clay soil, coloured red due to the presence of iron peroxide. Black soils sometimes occur in patches throughout the red soil areas. Red soils differ greatly in depth and fertility, and are deficient in nitrogen, phosphoric acid, humus and lime. The clay fraction of the red soils is rich in kaolinitic type of minerals.

Black Soils. These soils cover a large area in the country next in extent to alluvial soils. They are distributed over greater parts of Bombay, Kathiawar, Gujarat, Berar, the western parts of Madhya Pradesh, Andhra Pradesh and some portion of Madras, including the districts of Ramnad and Tirunelveli in the extreme south. Black soils are loamy to clayey in texture, and vary in depth from two to several feet, sometimes exceeding 20 feet. These soils have a lime *kankar* zone at some depths, and contain free carbonates, mostly calcium carbonate, mixed in them. They are characterised by the development of wide and deep cracks during the summer season, especially the heavy clays, where the cracks are more than three to four feet deep. Black soils are sometimes termed as tropical chernosems and are generally rich in montmorillonitic and beidellitic group of minerals. These soils exhibit a fair degree of fertility and are well-supplied with potash, magnesium and iron, but are generally low in nitrogen, phosphoric acid and organic matter. These soils are well-suited to the cultivation of cotton; rice is also grown, but mostly on soils ranging from lighter black to reddish in colour.

Laterite and Lateritic Soils. Laterite formations are characterised by compact to vesicular rock, comprising mainly a mixture of hydrated oxides of aluminium and iron. These soils are formed *in situ* by the leaching out of the bases from the parent rock and are derived by the weathering of several types of rock under the alternate dry and wet seasons of the monsoon regions. The soils are usually well-drained and are broadly divided into high and low level laterites. The former are pale in colour, shallow, gritty and poor in plant food nutrients. The latter have a finer texture, are deeper in colour, and contain a fair amount of humus. Agriculturally, these soils have poor fertility, and are deficient in nitrogen, phosphoric acid, potash and lime. Well-developed laterite soils are met with on the summits of the plateau and hills of the Deccan, Mysore, Kerala, Orissa, South Bombay and parts of Assam and West Bengal.

Saline and Alkaline Soils. These soils, locally known under various names such as *reh*, *kallar*, *usar* and *kharvat* are found in many parts of the country. In rice-growing areas, these soils are met with in Bihar, Uttar Pradesh, the Punjab, Bombay and coastal areas of West Bengal, Orissa and Kerala. These are either totally unfit for cultivation or give only poor crop yields due to the accumulation of soluble salts in the surface soil, producing a high degree of salinity or alkalinity.

The soluble salts present in the soil are mostly of sodium. These are injurious to plant-growth and sometimes form incrustations or efflorescences on the top layers due to the capillary rise of salt solutions from the lower depths. In canal-irrigated areas and coastal places where the sub-soil water table is high, the formation of

saline and alkaline soils is facilitated, as in the irrigated tracts of Bombay-Deccan, Madras and areas near the sea coast. Sometimes, due to the submergence of land by tidal waters, the coastal areas become saline and unfit for cultivation.

At many places in the country where copious irrigation water is available to wash down the salts to lower depths, saline soils have been reclaimed by flooding, improvement of drainage, etc., and put into profitable cultivation under rice and other crops. In the coastal belts in the districts of 24 Parganas and Midnapore in West Bengal, the inflow of tidal waters has been checked by raising bunds and dykes, and the soil brought under cultivation.

Peaty and Marshy Soils. Peaty soils occur in humid regions due to the accumulation of large amounts of organic matter in the soil. In addition, they may also contain soluble salts. Typically peaty soils, known as *khari*, are found in Kerala.

The low-lying areas formed by the extinct and dried rivers and lakes in the alluvial and coastal belts sometimes give rise to water-logged conditions and form marshy patches. These soils are generally bluish grey in colour due to the reduction of iron to the ferrous state, and contain varying amounts of organic matter. Marshy types of soils are found in the coastal tracts of Orissa, Sundarbans and other places in West Bengal, the central portion of north Bihar and the south-east coast of Madras.

DISTRIBUTION OF SOILS IN RICE-GROWING AREAS

The study of the soil in relation to rice crop production has been pursued in the country in various States, and Sethi (1940) and later, Sethi *et al.* (1952) have compiled a comprehensive survey of manurial requirements of rice in various regions of the country. The soils and cultivation practices vary in different rice-growing areas. The description of the soils of the different regions with their characteristic features is surveyed below and also shown in Fig. 5.

Assam. Rice in Assam is mainly grown on (i) alluvial soils in the Brahmaputra and Surma valleys, and (ii) laterite soils in the mountainous regions of the parts of the north-eastern State. The Brahmaputra valley is an alluvial plain, 450 miles long and about 50 miles broad, bounded on all sides except in the west by hills. The Brahmaputra river, rising in the northern slope of the mountains, flows with a sharp gradient and great velocity, depositing larger and coarser fractions. Hence, the soils of the valley are largely sands and sandy loams. Being situated in the heavy rainfall region, the soils are highly leached, low in lime content and acidic in nature. The potash content of the soils, both total and available, is fairly good, and the nitrogen and organic matter status is satisfactory. The land slopes on both sides of the rivers and rises up to the sub-montane regions. The *chapari* lands in the immediate neighbourhood of the river are heavily flooded during the rains, and grow a good crop of summer rice, if the floods do not come early in the season. The area behind this is low-lying, and grows *bao* (medium and deep water winter rice) and jute. As the land rises further beyond the reach of the flood, an excellent crop of transplanted rice is grown. In the sub-montane regions, the fields are irrigated from hill streams and transplanted rice, sugarcane and tea are grown.

The Surma valley is a flat plain, 125 miles long and 60 miles wide, and closed on three sides by the hill ranges. The Surma river and its tributaries rise in the

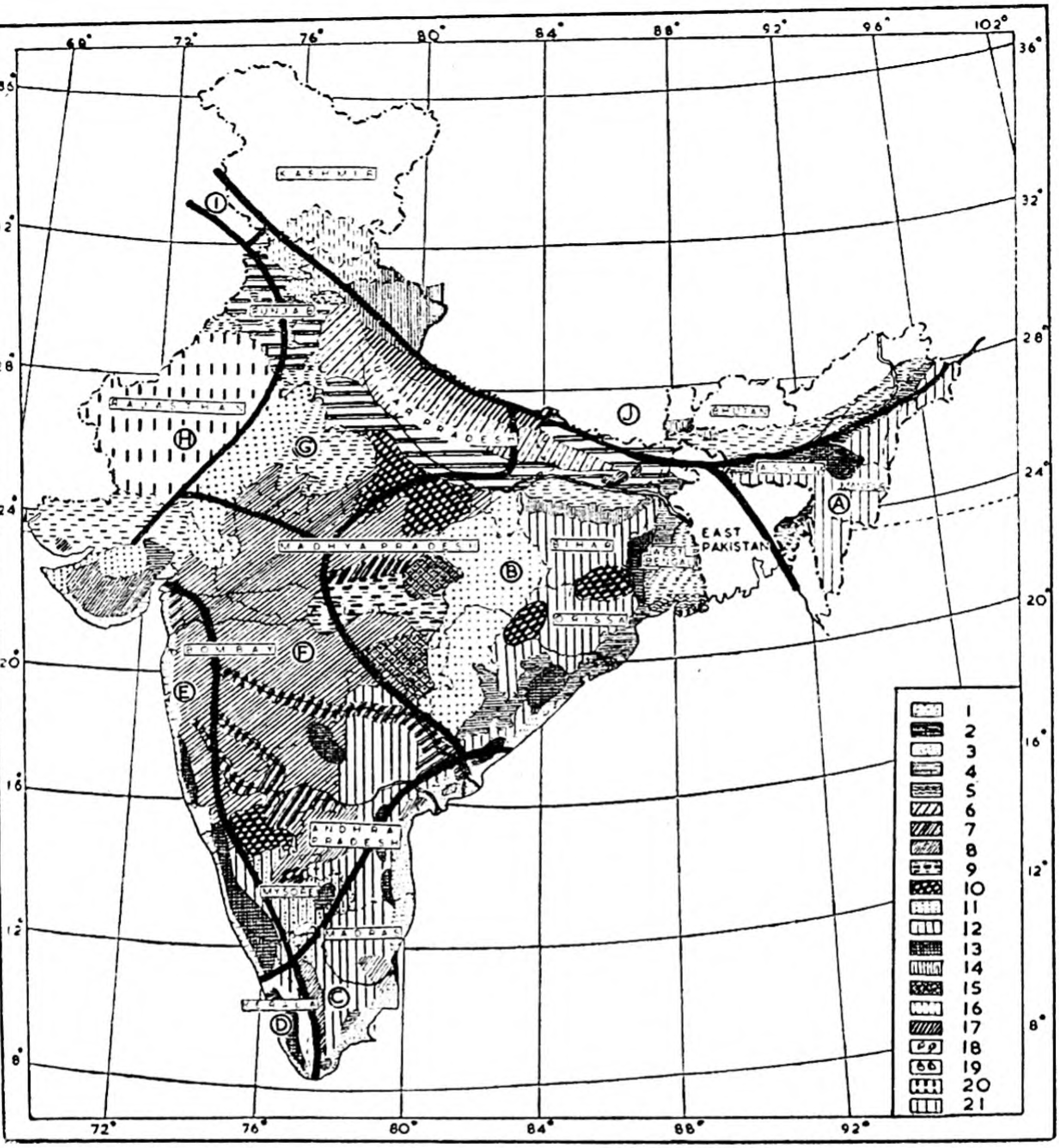


Fig. 5. General distribution of soils

1. Alluvial Soil. 2. Alluvial soil impregnated with varying amounts of salt. 3. Coastal sandy alluvium. 4. Old alluvium (red). 5. Saline and deltaic soil. 6. Calcareous soil. 7. Deep black soil. 8. Medium black soil. 9. Shallow clay loam. 10. Mixed red and black soil. 11. Red sandy soil. 12. Mixed red loam and red sandy soil. 13. Lateritic soil. 14. Forest and hill soil. 15. Gravelly soil. 16. Submontane region. 17. Terai soil. 18. Marshy land. 19. Peat soil. 20. Desert soil. 21. Red loam.

A. Very heavy rainfall (100″ and above). B. Heavy rainfall (50″-90″); considerable humidity (60-85). C. Months with greatest rainfall Nov. and Dec. (40″-20″). D. Very heavy rainfall (over 100″). Dry season three months. E. Very heavy rainfall (over 100″). Dry season seven months. F. Mean Jan. Temp. 65°-75°. Moderate rainfall (50″-20″). G. Moderate rainfall (50″-20″). Very hot and dry in early summer. H. Arid low land, rainfall below 20″. I. Rain in winter as well as in summer (40″-25″). Mean Jan. Temp. below 55°. J. Rainfall 60″-130″.

southern slope of mountains and flow in almost a level plain. The rivers are sluggish, and deposit a finer material. Hence, the soils in the valley are finer than those of the Brahmaputra valley. This area represents a vast deltaic expanse, liable to deep flooding in the rainy season, and as a result vast areas assume swampy conditions during that period. Occasionally, there are low-lying basins, locally called *hoars*, which retain water almost throughout the year. Here, fairly high-yielding rices are grown. The soils along the river banks are the most fertile tracts in the valley, fairly good in nitrogen and potash, and grow rice, jute and other crops. The western portion of Sylhet becomes a great swamp during the rains, and the late *aman* rice is grown here.

Rice in the State is also grown in the Khasi Hills on terraced and irrigated areas and in the valleys. The rice lands in the valleys are heavy loams, and contain a fairly large amount of organic matter.

The Assam soils are generally characterised by a fairly good nitrogen content, the average being about 0.15 per cent. In certain hilly areas, a nitrogen content of as much as 0.3 to 0.4 per cent. has been recorded. The soils are generally acidic in character, the acidity being low in the riparian tract. The average *p*H of the Assam soils is 5.5 and soils with a *p*H of 4.0 and below are not uncommon. In the heavy soils containing high percentages of nitrogen the average yield of paddy per acre is fairly high, and response to manures low. In the poorer soils, however, where the yields are below 1,600 lb. per acre, both nitrogen and phosphate fertilizers are recommended for pushing up yields.

West Bengal. Rice is grown all over the State, and the soils are broadly classified into laterites, red soils, alluviums, coastal soils and *terai* soils.

(i) Laterite Soils: Laterite and lateritic soils occur in the districts of Birbhum, Burdwan, Bankura and Midnapore. The land is undulating with tiny rivulets, and the soils are highly eroded. They are yellow-grey coloured on top and red below. Organic matter, nitrogen, available phosphate and calcium are low, and the soils have acidic reaction. The *p*H ranges from 5.5 to 6.5, nitrogen from 0.01 to 0.08 per cent., P_2O_5 from 0.01 to 0.05 per cent. and CaO and K_2O each from 0.01 to 0.4 per cent. Transplanted *aus* and *aman* rices are grown in terraced fields, and good yields are obtained only in fields situated at the bottom of the terraces. The soils are generally responsive to nitrogen and phosphate manuring. Buried laterites are found in this area at a depth of 10 feet and below, and over them lie alluviums brought down by the floods of Dwarakeshwar, Damodar and Cossaye rivers. The surface soil appears to be younger in formation. Rice yields here are not very much increased by nitrogen application alone, but when phosphate is added, high responses are obtained.

(ii) Red Soils: Tracts of red soils are found in the districts of Birbhum, Burdwan, Bankura, West Dinajpore and Midnapore. The soils vary in depth, and occur with and without occasional lime concretions in the profile. The area gives a chessboard appearance of red soils, lateritic soils and laterites. The soils are mildly acidic (*p*H 6.2 to 6.6) and poor in calcium, nitrogen and available phosphate. Rice is grown on terraces, *aus* on the upper and *aman* on the lower terraces. The soils are porous, and if the monsoon fails, the crop suffers badly. Rice grown in these areas responds well to nitrogen and phosphate manuring.

(iii) ALLUVIAL SOILS: These are divided into two families, the Ganga alluvium and the Vindhya alluvium. The Ganga family of alluvium is situated in the districts of Murshidabad, Nadia, 24 Parganas, Burdwan, Hooghly and a portion of Midnapore and riverine soils of both inundated and high land phase, flat land, lowland and upland soils are met with. These soils, in general, are deficient in nitrogen, which ranges from 0.02 to 0.09 per cent. being on the higher side only in the Ganga low lands. The soils respond to application of nitrogenous fertilizers and a yield increase of about 240 lb. per acre is obtained. The phosphate in the soil varies from 0.1 to 0.15 per cent. in the riverine and flat lands, and 0.03 to 0.06 per cent. in uplands and 0.06 to 0.1 per cent. in the low lands. Response to phosphate fertilization in the area is not significant. The *p*H of this family of soils ranges from 7.0 to 8.2, except in the uplands, where it varies from 6.0 to 7.5. Potash varies from 0.1 to 0.4 per cent. in the uplands and low lands, and 0.3 to 1.0 per cent. in the riverine and flat lands. Calcium oxide in the riverine and flat lands is high, ranging from 1.0 to 5.0 per cent. and even higher at places.

The riverine soils have an immature profile, and are sandy in nature. Cultivation of early *aus* is practised here. The Ganga flat lands have a more mature profile, and vary from clays to sands, depending on the local topography. The low land areas occur where depressions have been created by the meandering action of different rivers. These depressions receive the washings from flat or riverine lands and also deposits of large amounts of silt and clay from the diurnal tidal flows. During rains, these areas appear like lakes. *Aman* rices are grown here in shallow places, and *boro* in the deeper ones. The Ganga uplands are older alluvials having a moderate accumulation of clay in the soil profile and lime in the form of concretion in the subsoil. These soils are well suited to *aman* rices, and in the depression, *boro* rices are also grown.

The Vindhya family of alluvials is formed from the alluviums brought down from the Rajmahal Hills and the Chota Nagpur Plateau. These comprise Rajmahal, Damodar and Cossaye riverine soils, flat land soils and upland soils. They occur in the districts of Birbhum, Burdwan, Hooghly, Bankura and Midnapore, and respond well to nitrogen, but response to phosphate is not adequate, except in the clay type soils of the flat lands. The *p*H in the riverine soils varies from 6.5 to 7.2, and from 5.8 to 6.9 in the flat lands and uplands. The soils are low in nitrogen, which ranges from 0.005 to 0.02 per cent. in the riverine, and 0.02 to 0.06 per cent. in the flat and low lands. The phosphate varies from 0.01 to 0.05 per cent, lime from 0.3 to 0.7 per cent. and potash from 0.1 to 0.5 per cent.

(iv) COASTAL SOILS: Coastal soils of tidal origin in the State are next in importance to the alluvial tracts, and occur in the districts of 24 Parganas and Midnapore. Bunds or dykes are put to prevent the ingress of sea water, and sluices are constructed to allow the escape of rain water, gradually washing away the salts from the soil. These soils when reclaimed are rich in plant nutrients, and support a good crop of rice. The deposits are rich in calcium and magnesium and also contain, sometimes, half decomposed organic matter.

(v) TERAI SOILS. These soils occur at the foot of the Himalayas, the soil material being brought down by hilly rivers from heights of 10,000 feet and deposited at about 200 to 300 feet above sea level. The deposits are mostly sandy, raw

humus type, and deep black to grey black in colour. These occupy a majority of the rice areas in Jalpaiguri and Cooch-Bihar districts. The areas get water-logged during rain, and *aman* rices are grown. The soil is acidic, *p*H ranging from 4.7 to 5.8, poor in bases and available plant food material. Cultivation is precarious and yields are poor, either due to the heavy floods and transporting action of running water depositing huge amounts of micaceous sand, or due to drought conditions. A combination of nitrogen and phosphate fertilizers has been found to increase rice yields in these soils.

Bihar. Bihar has nearly 50 per cent. of the cultivated area under rice. The crop is grown both on the north and south of the river Ganga and also on the terraced hilly areas of Chota Nagpur. The Ganga divides the State into nearly two halves and the entire tract, both north and south of the river, is traversed by a number of tributaries feeding the main waterway. The soils of the State are broadly divided into three divisions: (i) Alluviums, north of the Ganga (ii) Alluviums, south of the Ganga and (iii) Red and brown soils formed on the parent rock. The alluvial soils north of the Ganga vary from clay loams to sandy loams and are neutral to somewhat alkaline in reaction, *p*H going above 8.0 in places where the calcium carbonate content is high. Two distinct zones of soil, non-calcareous and calcareous, are met with in north Bihar. Both types of soils have an open and porous structure and satisfactory drainage. Organic matter, nitrogen and available phosphate are all low. Non-calcareous soils are found in the humid regions having a rainfall of 55 to 60 inches, and cover the major portion of the districts of Champaran, Muzaffarpur, Darbhanga and Purnea. Soil reaction is on the slightly alkaline side with a tendency towards development of acidity in the extreme north. The calcareous soil region is in the lower rainfall area, having 40 to 45 inches of rain and covers the whole of Saran and southern portions of the districts of Champaran and Muzaffarpur. Leaching of soluble salts in this region is less pronounced, and the total phosphate is high, but the available phosphate is low. Soil reaction is alkaline (*p*H 8.2 to 8.4).

The alluvial soils in the south of the Ganga cover the districts of Patna and Gaya and parts of Shahabad. The soils are heavier and finer in texture than those of the northern part. The calcium carbonate content is less, and the soil reaction is sightly alkaline, tending to be neutral and rather acid towards the southern most part. Drainage is unsatisfactory in these soils. Nitrogen is low, but the available phosphate is comparatively higher. Some alluvium also occurs in the Sone Valley in Shahabad and Patna districts, where soils range from sands to clays, representing an admixture in varying proportions of the coarse sandy deposits of the Sone and heavy deposits of the Ganga. Soil reaction here is alkaline, available phosphate is medium and nitrogen reserve low. The rice crop is mainly concentrated in the south of the Ganga.

Red loams occur in the whole of the Chota Nagpur Division, and brown soils are found in portions of Bhagalpur and Monghyr districts. Available potash in the soils is sufficient, but total and available phosphates are low. The soils are acidic, *p*H varying from 5.0 to 6.8. Rice is the main crop in the Chota Nagpur area, and depends on the south-west monsoon.

Orissa. This State has 80 per cent. of the total cultivated area under rice

which is divided into four distinct regions: (i) the Coastal tracts, (ii) the Northern Plateau, (iii) the Central Plateau and (iv) the Eastern Ghat regions.

The Coastal tract comprises the basin of rivers Baitarani, Brahmani, Mahanadi and Rishikulya. This is the most fertile area of the State, and is composed of alluvial deposits varying in texture and containing 30 to 50 per cent. clay. Soils of the Mahanadi delta are low in soluble salt content and vary in *p*H from 5.0 to 8.0. There is preponderance of calcium in the exchange complex, but calcium carbonate rarely exceeds 1 per cent., nitrogen in these soils varies between 0.02 to 0.06 per cent., P_2O_5 from 0.05 to 0.10 per cent. and potash from 0.4 to 0.6 per cent. In the coastal area, both acidic and saline soils are found, the former in *pat* lands and the latter along and near the sea coast. The *pat* lands are submerged during the rainy season and are exposed only during spring. In such an area, spring rices are cultivated from December to April.

Saline lands are found near the confluences of rivers with the sea, where the rivers break up into a number of branches, forming several islands. These islands being close to the sea, often get tidal waters, making the soil saline with a high content of sodium salts. Reclamation of these soils is done by cultivators by raising ring bunds to prevent the inflow of tidal water, and then heavily green manuring the lands. Salt-resistant varieties are grown on such lands.

The Northern plateau of the State, consisting of the districts of Mayurbhanj and Keonjhar and parts of Khenkanal and Sundargarh districts has undulating lands. The soils here are classified as red soils, and generally are of low fertility. However, good fertile soils, heavy in texture, are found in the valleys of the plateau.

The Central plateau, a tableland comprising the districts of Sambalpur, Bolangir and Boudh-Phulbani and parts of Dhenkanal district has old alluvium soils and black soils, the latter with a mixture of limestone. Yellow soils and mixtures of red and black soils are also found in these areas. Soils in the districts of Angul and Sambalpur are shallow and rocky, and in some places pan formation is seen. These soils are poor in available P_2O_5, although the content of total P_2O_5 is sometimes high. The nitrogen content is also low.

The Eastern Ghat region, comprising parts of Ganjam, Koraput and Kalahandi districts, grows rice at an altitude of 1,000 to 4,000 feet. Laterite soils and red soils are met with in this area. The nitrogen content is high in the case of the Koraput soils, but low in the Ganjam soils. Both available and total P_2O_5 in the soils are fairly high.

Almost all soils in Orissa in general are low in nitrogen, and respond to nitrogen fertilization. Phosphate has also given response in certain locations.

Andhra Pradesh. Soils in the State range from sandy loams to heavy clays and are broadly classified into four groups, (i) black cotton soils of the *regur* type, mainly in the districts of Kurnool, Guntur, Cuddapah, Krishna, Adilabad and Khammam, (ii) red soils and laterite soils, concentrated in the districts of Anantapur, Kurnool, Cuddapah, Chittor, Nellore, Nizamabad, Medak, Hyderabad, Karimnagar, Warangal, Nalgonda, Mahbubnagar and major portions of Srikakulam, Visakhapatnam and East Godavari districts, (iii) alluvial soils, pertaining to the three deltaic areas of Godavari, Krishna and Pennar rivers, and (iv) coastal sands and sandy loam.

The black soils, known as the *regur* soils and ranging from grey to black in colour, occur in the flat and gently sloping areas and in the valleys. Both shallow and deep types, ranging from a foot to 20 feet deep are met with. These soils are heavy in texture, comparatively ill-drained and are at places high in soluble salt content. In the deeper soils, there is an accumulation of calcium carbonate and gypsum at the lower depths of the profile and the *p*H value of these soils ranges from 7.0 to 8.5. The soils are low in humus and nitrogen, and are deficient in available phosphate. The black soils are the predominantly cotton-growing areas of the State. Rice is also grown in some areas of black soils and responds more to phosphate application, when the same is applied in conjunction with nitrogenous fertilizers. Improvement of drainage, and application of phosphatic and nitrogenous fertilizers are essential to get good crop yields on these soils.

At one time, over 100,000 acres of these *regur* soils under the Nizam Sagar Project were excluded from irrigation as it was believed that the heavy nature and poor drainage of these soils led to the development of salinity and alkalinity and made them unifit for cultivation. Recent research on these soils, however, has shown that they have an acute phosphate deficiency and could be put to profitable cultivation by providing adequate drainage, application of organic manures and readily available phosphatic fertilizers.

Red soils (*chalkas*) in the State range from brown to red in colour and are mostly shallow, ranging from 6 to 24 inches. These soils vary in texture from sandy to loamy, are well drained and have a low salt content, *p*H ranging from 6.5 to 7.5. They are low in humus, nitrogen and phosphoric acid. The soils are comparatively easy to manage for rice cultivation, but need frequent incorporation of bulky organic manures and green manures. Rice on these soils responds more to nitrogen than to phosphatic fertilizers.

The rich rice-growing areas of the State are the deltaic areas of the Godavari and the Krishna. The soils in the deltaic areas and along the coast line are alluvial, the composition of the strata varying with the nature of silt brought down by the rivers from the catchment areas. The Godavari alluvials are different from those of the Krishna. The river Godavari, flowing through trap rock over a large portion of its course, brings down rich, black, fertile mud and deposits the same in the deltaic areas.

Soil surveys of the rice-growing areas of Guntur, West and East Godavari and Krishna districts were conducted in 1914 and 1938, with a view to finding out the manurial requirements of rice in these tracts. All the rice soils in this area are characterised by higher amounts of CaO, MgO, total and available K_2O and P_2O_5, but are deficient in nitrogen.

Patches of alkaline soils occur both in the red soil and black soil areas, and are confined to low lying locations with impeded drainage. These areas are reclaimed by providing adequate drainage, green manuring and application of gypsum. The use of phosphates is also recommended in these soils to get satisfactory yields.

Madras. In Madras, rice is grown in three distinct regions. The first region consists of Salem, Coimbatore, Madura, Ramanathapuram and Tirunelveli districts in the central and southern parts of the State. This is a zone of low rainfall,

not exceeding 30 inches. Red, black and mixed types of soils are found in this area. In the Periyar tract in Madura district, nitrogen in the soils is generally satisfactory, but phosphate, both total and available, is inadequate ; potash is sufficient.

The alluvial soil tracts found along the banks of the Cauvery and the deltaic areas in Tanjore district form the second region. The delta soils are deep and rich, and vary from clay loams to heavy clays with a *p*H of about 7.5. The finer fractions are below 50 per cent. and the clay content is 30 per cent. on an average. The nitrogen content is low, being less than 0.06 per cent. half the area having even less than 0.04 per cent. Nitrogen-rich lands are usually found on the banks of the Coleroom river. Available phosphate in the soils is very low, but potash is adequate. Phosphate-rich lands are also met with on the banks of the Coleroom river.

The third region consists of the east coast districts of Chingleput, South and North Arcot with a rainfall of over 40 inches. The area predominantly comprises red soils, sandy loams in texture. In the Chingleput area, soils near the coast are high in sodium chloride. Black soils are found in South Arcot, and also in the neighbourhood of the principal rivers in North Arcot. The soils are deficient in organic matter and poor in plant food nutrients.

Kerala. The cultivated area of the State can be divided into four distinct regions: (i) the Malabar coast, a region of undulating land with low hills and valleys, (ii) the eastern mountainous area covered with forests and plantations mainly of tea, (iii) the midland area, lying between the low lands and the mountainous region, consisting of an undulating narrow strip of land with dense vegetation, and (iv) the low land area consisting of a narrow strip of flat land, lying along the coast and having a width of about 5 to 10 miles, divided into strips by a succession of backwaters, connected by navigable canals. Rice is grown in the State on terraced hills and valleys of the Malabar coast, in the valleys of the midland region. Rice is also the main crop in the coastal region.

The soils in Malabar coast and the south of the State are red and lateritic, and belong to the red ferruginous series comprising clay and sand. These soils contain fair amounts of nitrogen, but are particularly deficient in lime and magnesia. Total phosphate is adequate, but available amounts are low. As regards potash, the total amount is fair, but available potash is just enough to meet the requirements. Recent soil formations in the northern part of the Travancore area of the State are sandy tracts between the sea and the backwaters. The soil belt along the sea consists of sand to sandy loams.

The alluvial soils in the State are found along the banks of rivers, chiefly in Kuttanad, and range from sandy to rich peats. These constitute the low-lying tracts, believed to be once part of the sea, and filled up by gradual deposits brought down by the Pampa and other rivers. There are single and double-cropped lands. Nitrogen and potash in these soils are fairly good, but phosphate is low. In addition, there is the Vembanad reclamation area comprising the Vembanad lake, a large expanse of backwaters, extending from Allepy to Cochin. A portion of this lake, more than 20,000 acres in extent, has been reclaimed and is an important rice cultivation area of the State. Further areas are under reclamation. The soils

here are acidic in reaction and rich in nitrogen and other nutrients. A system of rice-growing known as *cole* cultivation is practised in the reclamation area.

In the Ambalapuzha, Kunnathunad, Vaikom and Shertallai areas, *peaty* or *khari* soils are found. These remain submerged during the monsoon, and after the rains are over, are put under rice cultivation. The lands are black, heavy and highly acidic with *p*H sometimes as low as 3.9. Organic matter in these soils varies from 10 to 40 per cent., K_2O from 0.2 to 0.7 per cent., Fe_2O_3 and Al_2O_3 from 20 to 30 per cent. and P_2O_5 from 0.1 to 0.2 per cent.; available phosphate in the soils is rather low. Sometimes, the soils are highly toxic to plants and attempts at reclamation with liming have not met with much success. The *khari* areas of the State are subject to inflow of the tidal rise of the sea waters and also have a subsoil water containing soluble salts within a few feet of the surface. Accumulation of salts, therefore, in the topsoil has rendered large areas unfit for rice cultivation.

The Nanjanad area has grey blue soils, heavy in texture and rich in plant food material, and is the best rice-growing area of the State. The soils are generally somewhat alkaline.

In the Cochin area of the State, 50 per cent. of cultivated area is under rice. Alluvial, red and laterite soils are found. *Cole* lands are found in the Trichur taluka, and the soil in these lands is alluvial. Here rice soils have fair amounts of nitrogen, but are poor in available phosphate, potash and lime.

Mysore. Soils of the State are classified mainly as black, red, and laterites. Mixed red, yellow and grey soils are also met with. The black soil region is mostly in the north of the State, covering the districts of Raichur, Gulberga, Bijapur, Dharwar, parts of Belgaum and also a small area of Chitaldurg and Tumkur districts. These soils are fairly heavy in texture and generally rich in lime and magnesia. Red soils are predominant mainly in the eastern tracts of the State, especially in the districts of Bangalore, Kolar, Mysore, Mandya and Tumkur. These soils are generally lighter in texture than black soils. Laterite soils occur in Karwar and Belgaum districts and the western parts of the districts of Shimoga, Hassan, Kadur and Mysore.

Rice in the State is grown (i) as a rainfed crop, usually broadcast in the hilly areas of Malnad tract, where soils are generally poor, (ii) in the flat rainfed basin having irrigation facilities, and (iii) the newly added areas of Belgaum, Karwar and Dharwar districts formerly in Bombay State. The rice growing areas of Shimoga, Mysore and Hassan, mainly comprise the red soils ranging from sandy to loamy in texture. In the Marthur area in Shimoga, the soils are generally lateritic. In the Irwin canal areas, soils are red, yellow and brown, and open in texture. The laterites and lateritic areas of Belgaum and Karwar districts are poor in lime and base status, and are generally acid in reaction. The mixed soils of Dharwar vary in colour from dark brown to medium black, and range in *p*H from 5.3 to 6.9. These are fair in bases and are well supplied with phosphates and potash, but rather low in nitrogen.

Rice soils in the State are generally low in nitrogen and available phosphate, but are adequate in potash. Nitrogen appears to be the predominating factor in the manurial requirements of rice, both under irrigated and rainfed conditions.

Bombay. Most of the rice area in the State is in the western parts which receive over 100 inches of rain per year and record high yields. The soils in the State are broadly grouped as (i) the deep and medium black soils derived from trap rock, (ii) the alluvial soils, and (iii) the laterites and lateritic soils. The rice-growing areas of the State are as follows.

Rice is grown on the alluvial soils in north and south Gujarat, Broach and Surat districts. Soils here vary from sandy loam to clay loam in texture, and have a *p*H of 5.6 to 8.8. These soils are low in lime reserve, particularly in the Broach area and are more or less base saturated. They are generally low in nitrogen, but fair in phosphate and potash.

Thana and Kolaba districts grow rice in the eastern portions, on soils derived from trap rock. These soils vary in texture from coarse sands on the hill slopes to clay loams in the valleys. Soil reaction ranges from *p*H 5.7 to 8.8 and the soils are poor in nitrogen, but are well supplied with phosphate and potash. The western parts of these two districts have coastal salt lands, where coarse salt-resistant rices are grown.

The Deccan plateau in the districts of east Khandesh, Nasik, Poona, North and South Satara and parts of Kolhapur grows rice on medium black soils. The majority of these soils are calcareous, and thoroughly base saturated. They are alkaline in reaction, the *p*H ranging from 7.5 to 8.5, and are poor in nitrogen, but fair in phosphate and potash.

Parts of Kolhapur district and the whole of Ratnagiri district grow rice on lateritic soils. These soils are characterised by poor lime and base status and are acid in reaction, the *p*H ranging from 3.6 to 5.9. They are fairly well off in nitrogen, but low in phosphate and potash.

Rice is also grown in the Wain-Ganga basin in Bhandara district of the former Madhya Pradesh. Here rich black soils, ranging from loamy to clayey in character, are met with. A large area in this district is covered by *Morand II*, a clayey soil, and *Sehar*, a loamy soil, both well suited for the growing of rice.

Madhya Pradesh. Rice here is exclusively a monsoon crop. The principal rice growing areas of the State are as follows:

1. The eastern districts comprising Drug, Raipur and Bilaspur in the Chhatisgarh Division of the State form the main rice-growing tract, the crop being mostly broadcast and its success depending on a well-distributed and adequate rainfall. The soils here in the Mahanadi basin are light sandy, red and yellow. The rice soils in the Chhatisgarh Division vary in chemical and physical composition, and light soils, loams and clays are found. These are deficient in phosphate, which ranges from 0.02 to 0.07 per cent. and are low in humus and nitrogen. The *p*H ranges from 5.4 to 8.4 and the calcium present in the soil is mostly in an exchangeable form. The yield and quality of rice here have been found to be influenced by the soil texture. The rice soils of this tract are locally called *dorsa* and *matasi*. *Dorsa* has dark grey colour, and is a mixture of light *matasi* and black heavy *kankar* clays, while *matasi* is a fine-grained yellow loam, and is considered ideal for growing rice.

2. The Wain-Ganga basin in Balaghat has rich black soils on either side of the Wain-Ganga, the Bag, the Deo and other rivers. These soils are formed by the alluviums brought down by these rivers. West of Wain-Ganga, the soils are also

black, but closely resemble the soil of the Chattisgarh plains. The clay content in these soils is more in the lower layers than in surface soil, and *p*H varies from 5.6 to 8.4.

3. In the northern portions of Seoni, Mandla and Jabalpur, the rice area is small, and is confined to places with irrigation facilities from tanks. The soils here are mostly of *dorsa* type. Jabalpur has light black soils, which are not very deep. *Domatta* and *sehra*, the two medium soils mostly used for rice cultivation occupy a large area in Jabalpur district. In Mandla, most of the area is covered by *barra*, a poor soil, but a good crop of rice is grown south of Haveli *tehsil* in this district.

The soils in the State are low in humus, nitrogen and phosphate. Rice soils, practically all over the State, respond to application of organic manure and nitrogen fertilizers. The use of phosphate is also recommended.

Uttar Pradesh. Rice cultivation in this State is confined to (i) the mountainous regions in the north and north-west, (ii) the submontane regions or the *terai*, a strip of land stretching along the northern boundary at the foot of the Himalayas, and (iii) the fertile Ganga alluvium in the centre and in the east of the State. The rice crop comprises nearly 18 per cent. of the total cropped area, and is mainly concentrated in the eastern and central parts of the State.

The soils of the mountainous regions are usually shallow with underlying rock. Here the land is formed in terraces for cultivation and the soils of these terraces have assumed varying depths. Brown soils, Podsols and meadow soils are met with in this area. Both rice and wheat are grown in the valley of this range, depending on the suitability of growing conditions.

The *terai* area is largely covered with forests, and where these forests have been cleared, rice and sugarcane are grown. The soils are divided into three broad divisions: (i) The *terai* tract wet land soils, (ii) the *khadar* area riverine soils and (iii) the upland soils. The wet lands, known locally as *mar*, are clay loams in nature with sufficient organic matter but are imperfectly drained. The *khadar* soils have been formed by the alluvial deposits of numerous rivers and lie almost as parallel strips between these rivers. The soils have colour ranging from ashy grey to brownish grey on the surface, and the texture varies from loam to silty loam. In certain places, these soils are highly productive. The uplands are at higher level than the *khadar* soils and vary in texture from sandy to sandy loams, sand hills being common in certain areas. These soils are well-drained, and produce luxuriant crops if irrigation is available. Soil reaction in the surface soils of *terai* is round about neutrality. Nitrogen varies from 0.035 to 0.057 per cent. and phosphate from 0 012 to 0 21 per cent.

Alluvial soils in the western, central and eastern regions are sandy loams, clay loams and clays, and are generally quite fertile, except in places where these have degenerated into *usar* soils containing a high content of sodium bicarbonate or sodium carbonate, and have a high *p*H. In the central and eastern regions, the soil *p*H varies from 7 0 to 7.5. In the central region, the total nitrogen in the surface soil ranges from 0 031 to 0.137 per cent., and phosphate from 0.11 to 0.64 per cent. In the eastern region, the ranges are 0.02 to 0.04 per cent. for nitrogen and 0.05 to 0.19 per cent. for phosphate.

The Punjab. Rice is relatively a minor crop here, but the State produces fine quality table rices. The crop is grown in two definite zones, the first being the irrigated zone served by inundation canals, and the other depending on the rains or small rivulets on the terraced hill slopes. The soils in the plains, the irrigated areas, belong to the Indo-Gangetic alluviums, and vary from loam to sandy loams. Soil reaction is generally alkaline, and the soils are deficient in organic matter and low in nitrogen. The soils on terraced hill slopes are comparatively higher in humus and nitrogen, but deficient in phosphoric acid. Rice generally responds to nitrogen in the Indo-Gangetic alluviums.

CHAPTER 5

IRRIGATION, DRAINAGE AND WATER REQUIREMENTS

India has the largest mileage of irrigation canals in the world. In the North, the rivers are fed by the melting snows of the Himalayas. Due to the construction of dams across rivers and a network of canals, water is made available for irrigation purposes. In the Peninsular Plateau, the rivers are seasonal, depending upon the rainfall received from the monsoons. Reservoirs with large catchment areas have been constructed for storing rain water for irrigation purposes. Besides, water from tanks and wells is used for the irrigation of crops. It is estimated that during the year 1954-55, about 55 million acres were irrigated from various sources (*Agricultural Situation in India*, 1956) as shown below.

	Canals	Wells	Tanks	Others	Total
Area irrigated (million acres)	22.3	16.4	9.8	5.9	54.4

It is estimated that an additional area of 21 million acres will be brought under irrigation during the Second Five Year Plan period—12 million through large scale irrigation schemes, and 9 million through minor irrigation schemes.

The bulk of the rice crop, however, depends upon rainfall for its water supply, and only about 20 per cent. of the rice area has irrigation facilities to supplement the water received from rainfall. The main cause of low yields and uncertainty of rice harvests is the dependence of the crop on the rains. Erratic distribution of rains or failure of the monsoons may cause complete or partial failure of the rice crop. The yields of the crop vary from place to place, according to the availability of water. In the north-east region and the west coast of the Peninsula, which have adequate and dependable rainfall, good yields of rice are obtained. An assured and timely supply of irrigation water has a great influence on the yield of the crop, as the planting and other agricultural operations can be done expeditiously, and at the proper time. In the southern States of Andhra Pradesh, Madras and Mysore, where a large percentage of the rice area is irrigated high yields are usually obtained.

The problem of flood control is also intimately connected with that of irrigation. Most of the rivers, which are sources of irrigation supply, cause considerable damage to agriculture, when they are in spate due to an excessive rainfall at their source in the mountain regions or in the valleys they pass through. Therefore, flood control is being given considerable attention in the execution of the modern multi-purpose projects.

Attention is also being given to minor and small irrigation schemes. The construction of embankments, irrigation channels and sluices and the

sinking of tube-wells are being undertaken for bringing more rice area under irrigation.

Drainage. In most of the low-lying delta regions, drainage is defective. The subsoil water table rises and the land remains submerged under water for a long period. In such areas, there is no surface movement of water, and the whole area becomes a vast swamp. Varieties of rice commonly grown in such areas withstand the prevailing water conditions.

Though during the monsoon the land is inundated, it remains dry during the off season, and the subsoil water table goes down. The natural drying of soil is beneficial for the maintenance of soil fertility. With the availability of perennial irrigation supply and consequent intensive cultivation of land, the subsoil water table during the dry season may not subside, thereby causing permanent damage to the soil. The extent of damage will, however, depend on the nature of soil and the cropping pattern. It is necessary, therefore, that side by side with the irrigation system, adequate provision for drainage is also made.

Water Requirement of Rice Crop. Though India has the largest irrigation system in the world, comprehensive data on the water requirements of different crops are not available. In recent years, more attention has been paid to the water requirements in relation to soil conditions of certain commercial crops like sugarcane, which are mostly grown under irrigation and some very useful data have been collected. Unfortunately, very little information is available regarding the rice crop, and whatever we have is empirical, and is not based on comprehensive research.

The water requirement of rice is larger than that of any other crop of a similar duration. It varies with the soil, climate, cultivation practices and the variety grown. An efficient use of water rests fundamentally on the extent of information on the optimum relationship between crop-yield and water requirement.

The term 'water requirement' as used in plant physiology, means the ratio of the weight of water transpired by a plant during its growth to the weight of dry matter produced, and is known as the transpiration ratio. This ratio is different for different plants, and varies with the conditions of growth. Besides transpiration losses, water is also lost from the soil surface by evaporation. Therefore, the absolute water requirement, or the *consumptive use* of water, is defined as the quantity of water in acre-inches per crop-season absorbed by the crop, together with the evaporation from the crop-producing land. From the agricultural and irrigation points of view, the total water requirement of a crop is equal to the *consumptive use* of water plus the percolative loss, the surface run-off and the loss in distribution.

Water Transpiration Ratio for Rice Crop. Experiments to determine the minimum water requirement of rice have been carried out in Assam and at the University of Banaras. The investigations were conducted under controlled conditions in pots, and the standard methods adopted by Briggs and Shantz were followed. Ganguli (1950) from Assam reported that the transpiration ratio varies with the duration of the varieties and is influenced by various environmental factors. The data obtained by him are given below.

TABLE 5. EFFECT OF SOILS ON WATER REQUIREMENT OF RICE

Nature of soil	Average water transpired in grams	Total dry matter in grams	Water requirement—Transpiration Ratio
Clay	6,735.84	10.25	657.16
Loam	6,339.89	8.75	734.56

The water requirement is lower in heavy clay soils than in loamy soils.

TABLE 6. EFFECT OF LENGTH OF MATURATION PERIOD ON WATER REQUIREMENT OF RICE

Variety of rice	No. of days from transplanting to flowering	Average water transpired in grams	Total dry matter in grams	Water requirement—Transpiration Ratio
Tepi Dumai	46	6,921.66	15.53	445.58
Basmati Aus	65	12,673.87	24.76	511.74
Baurash Murali	76	18,610.47	34.93	532.52
Mow birain	109	25,346.32	47.32	537.78
Sail badal	118	26,045.12	44.09	590.78
Latisail	123	24,585.13	40.08	613.40
			Average	538.60

The transpiration ratio varies directly with the duration of the variety.

TABLE 7. EFFECT OF DIFFERENT FERTILIZERS ON WATER REQUIREMENT OF RICE

Treatment	Average water transpired in grams	Dry matter in grams	Water requirement—Transpiration Ratio
1. No manure (control)	24,428	43.82	557.5
2. Cow-dung	21,024	32.64	644.1
3. Ammonium sulphate	32,471	50.89	638.1
4. Ammophos	30,994	42.61	727.4
5. Ammonium sulphate+superphosphate	38,596	61.30	629.6
6. Cow-dung+superphosphate	33,449	59.41	563.0

The above data indicate that the water requirement is minimum in the control plot (no manure) and highest with ammophos application.

Singh *et al.* (1935) also determined the water requirements of varieties differing in length of maturation period, and the data obtained by them are given below.

TABLE 8. WATER REQUIREMENTS OF DIFFERENT DURATION VARIETIES (BANARAS UNIVERSITY)

Variety	No. of days from transplanting to harvesting	Average water transpired per plant in grams	Average dry weight per plant in grams	Water requirement—Transpiration Ratio
Kuari	85	1,825.8	4.62	395 5
Jhengi	99	3,976.0	8.36	475 13
Karahni	99	3,211.0	6.24	514 6
Dehula	99	2,516.4	4.79	525 4
Badli	106	4,116.0	8.78	468 4
Saro	106	5,450.8	10.90	500 3
Karangi	106	3,173.4	6.33	502 7
Jilhore	120	4,731.4	7.50	630 5
Kasturi	120	4,842.0	7.62	635 5
			Average	519

Thus the water requirements of varieties vary with their duration.

Singh *et al.* (*l.c.*) also investigated the 'critical' periods of water requirement in the life cycle of the rice plant. This was calculated by dividing the weekly transpirational loss of water by the dry matter produced during that week. The following marked periods of high water requirement were observed in the life cycle of the rice plant.

1. The initial seedling period, covering about 10 days.
2. The pre-flowering and flowering period, covering about 25 days.
3. Grain formation period, covering about five to seven days.

The water requirement of the rice plant is the highest during these periods, and the crop is adversely affected in case of any deficiency of water during these 'Critical' periods.

Water Requirement of Rice Based on Field Experiments. The water requirement of rice under field conditions varies according to the soil, climate, cultural practices and the duration of the variety grown, and an efficient use of water can only be made if the optimum requirement of water for a particular condition is known. The irrigation department is primarily concerned with achieving high 'duty' which is determined by the total area cultivated under the crop with one *cusec* of water i.e., continuous flow of cubic foot of water per second. The rice crop 'duty' varies with different tracts, depending upon the nature of the soil and the underground water table. Besides the total requirement of water, the water needed at different stages of crop growth is also important, but very little data are available on this aspect. According to Ramiah and Vachhani (1951), a rice crop of about 150 days duration will require about 75 acre-inches of water, including rain and irrigation. Of this, about 25 inches will be required for the

raising of the nursery and preparation of land (puddling and transplanting), 40 inches from planting up to the time of flowering and further 10 inches up to the time of ripening.

Depth and Interval of Irrigation. Experiments have been conducted in different areas on the depth and interval of irrigation for the rice crop. Varying depths of water, ranging from two to five inches and at intervals of 3, 6, 9 and 12 days were tested. It was noted that yields obtained were in proportion to the quantity and the frequency of water supplied. Smaller quantities at shorter intervals were found to be beneficial for the rice crop. A depth of two inches of water at intervals of three to four days was found to give the best yield.

Irrigation experiments conducted in Madras and Andhra Pradesh indicated that by intermittent drying and irrigating the field every third day, a crop yield of the same order was obtained as by maintaining continuously a three-inch depth of water in the field. Results obtained at Nagina in Uttar Pradesh indicate that the frequency of irrigation was as important for the high production of rice as the 'delta' or the total quantity of water supplied. A small dose of two inches given every fourth day was found to give the best yield.

CHAPTER 6

RICE CULTURE

Rice-growing conditions obtainable in the different rice regions largely determine the system of cultivation. The chief factors, namely, situation of the land, type of soil, class of rice, season, intensity and distribution of rainfall, irrigation resources and special agronomic features, condition and influence the system of cultivation to a great measure. There are three principal systems of rice cultivation, *viz.*, 'dry,' 'semi-dry' and 'wet.' The 'dry' or upland rices are sown broadcast in the high level lands with the outbreak of the monsoons. They are called *aus* in West Bengal, *aus* or *ahu* in Assam, *beali* in Orissa, *bhadi* or *kuari* in Uttar Pradesh, and are of 90 to 110 days duration. The 'wet' or lowland rices are mostly transplanted, and are of five to six months in duration. The 'semi-dry' rice is grown broadcast as a 'dry' crop for about two months and when more water is available, after the strengthening of monsoon, it is treated as a 'wet' crop. The main features of these systems of cultivation are similar in all the rice-growing areas, with local variations in the method of sowing and other cultural operations. The three systems of cultivation are described below.

THE 'DRY' AND 'SEMI-DRY' SYSTEMS

These systems of cultivation are met with in all the rice-growing States, but are mainly confined to tracts which get either the South-west or the North-east Monsoon or both, and do not have adequate irrigation facilities. The area under the 'dry' system of cultivation is, however, rather limited, but there are large areas under the 'semi-dry' system in Orissa, Bihar, Uttar Pradesh and parts of Madras and Andhra Pradesh. In West Bengal and Bombay, though rice is grown mainly with the help of the South-west Monsoon rains, most of the crop is transplanted, and 'semi-dry' cultivation is not practised. However, in localities with moderate rainfall, the 'dry' system of cultivation is adopted.

Since it is difficult to predict when the monsoon would break, the seed is sown in the wake of the pre-monsoon showers or even earlier in the dry soil, in anticipation of rains. The lands for the 'dry' system of cultivation are, therefore, ploughed a number of times in summer as in South India or in winter as in Uttar Pradesh, Orissa, Assam and West Bengal, for obtaining the necessary tilth, and the available organic manure is applied. As the sowing is usually done in May-June in the case of the crop dependent on the South-west Monsoon and in September for the crop dependent on the North-east Monsoon, the practice of opening up the soil in the summer and/or in winter is adopted in order to ensure timely sowing and to utilize the monsoon rains to the best advantage of the crop.

In the 'semi-dry' system, the preparatory cultivation is the same as that adopted for the 'dry' system. Usually, in July-August, when the South-west Monsoon is active, the rain water is impounded in the fields and the young crop of five to six weeks is ploughed crosswise with a light narrow wooden plough with

FIG. 6. Sprouted seeds

FIG. 7. Broadcasting sprouted seeds

FIG. 8. Wet seed-beds

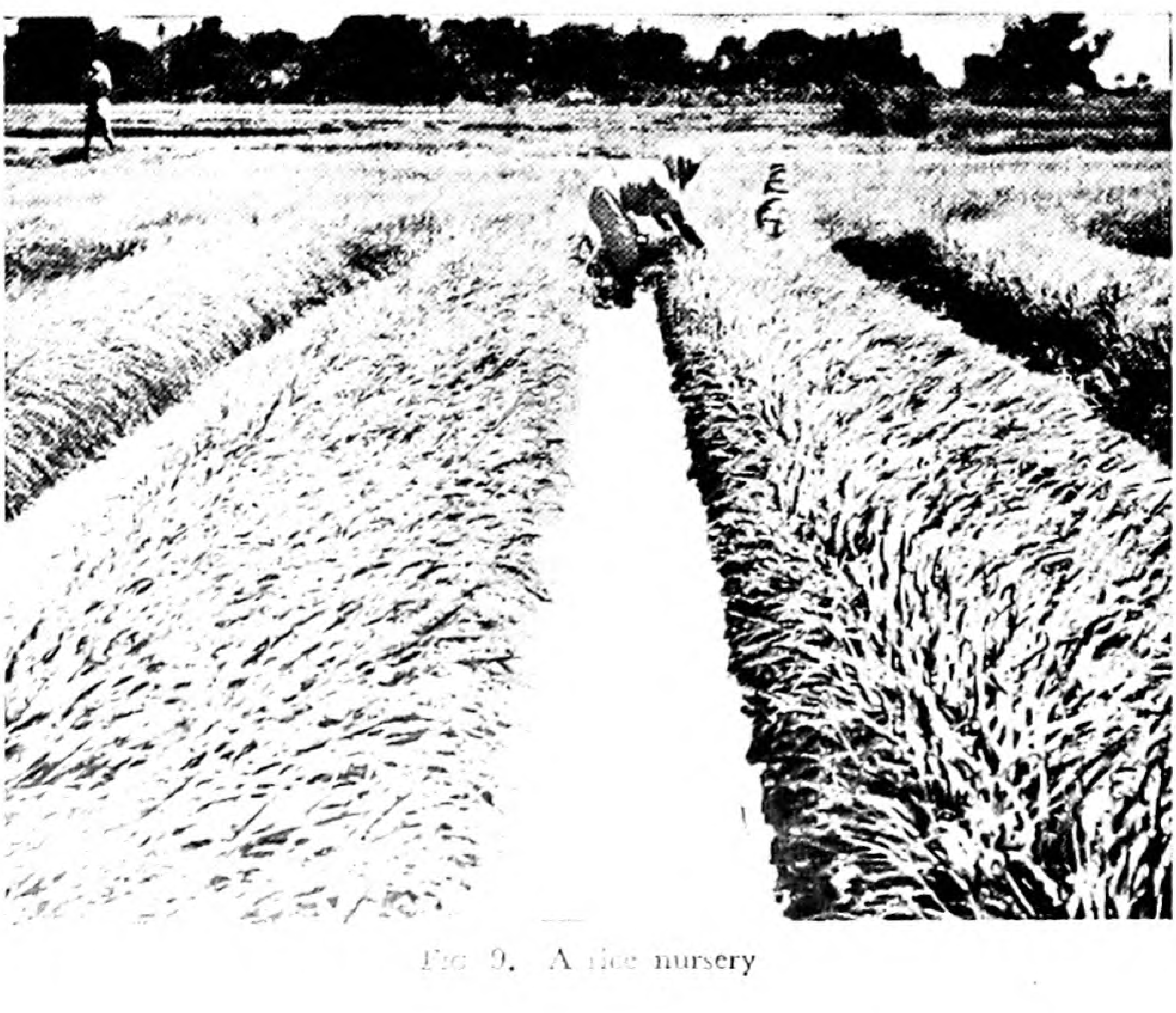


FIG. 9. A rice nursery

Fig. 10. Burying green manure with bullocks

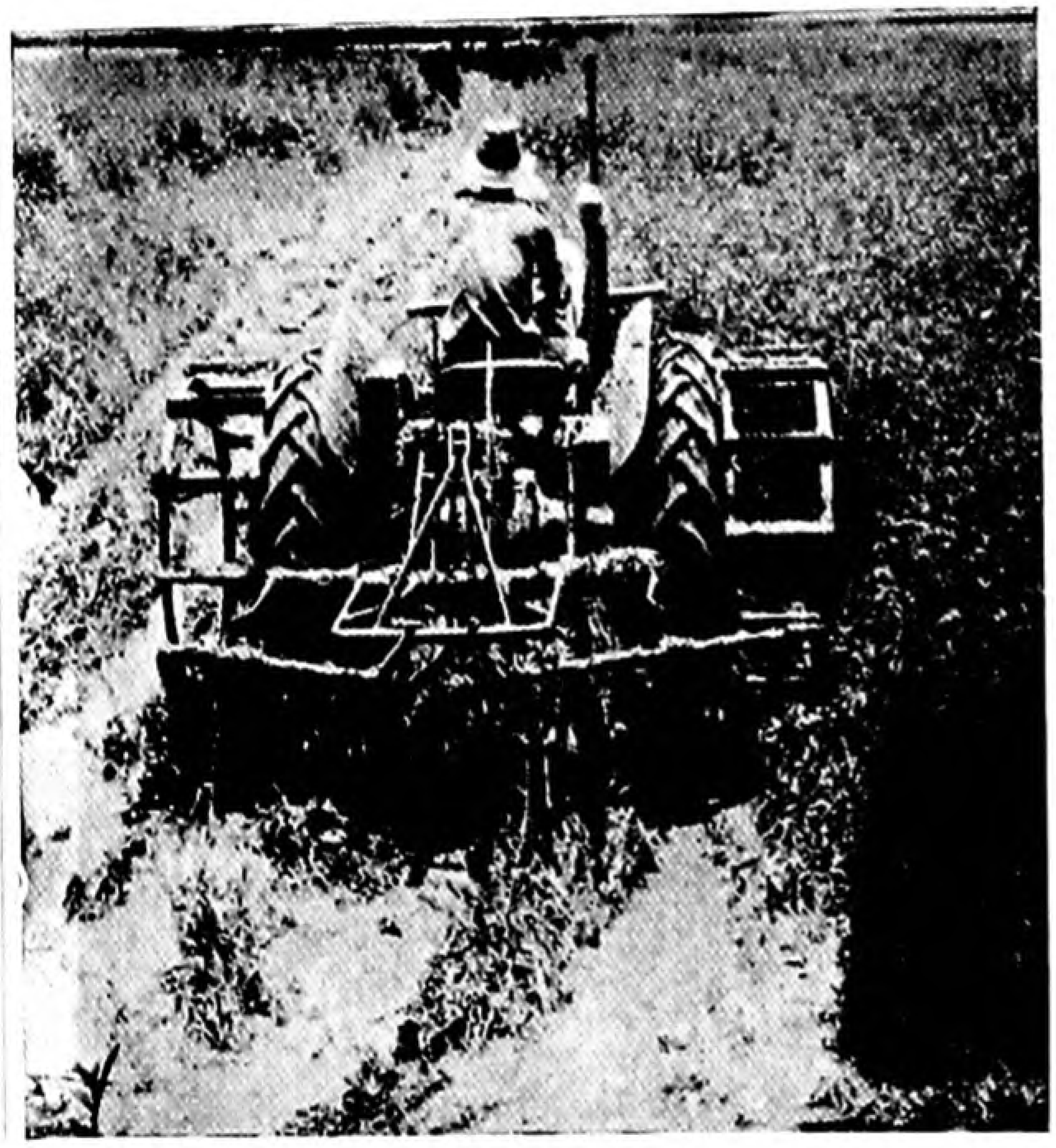
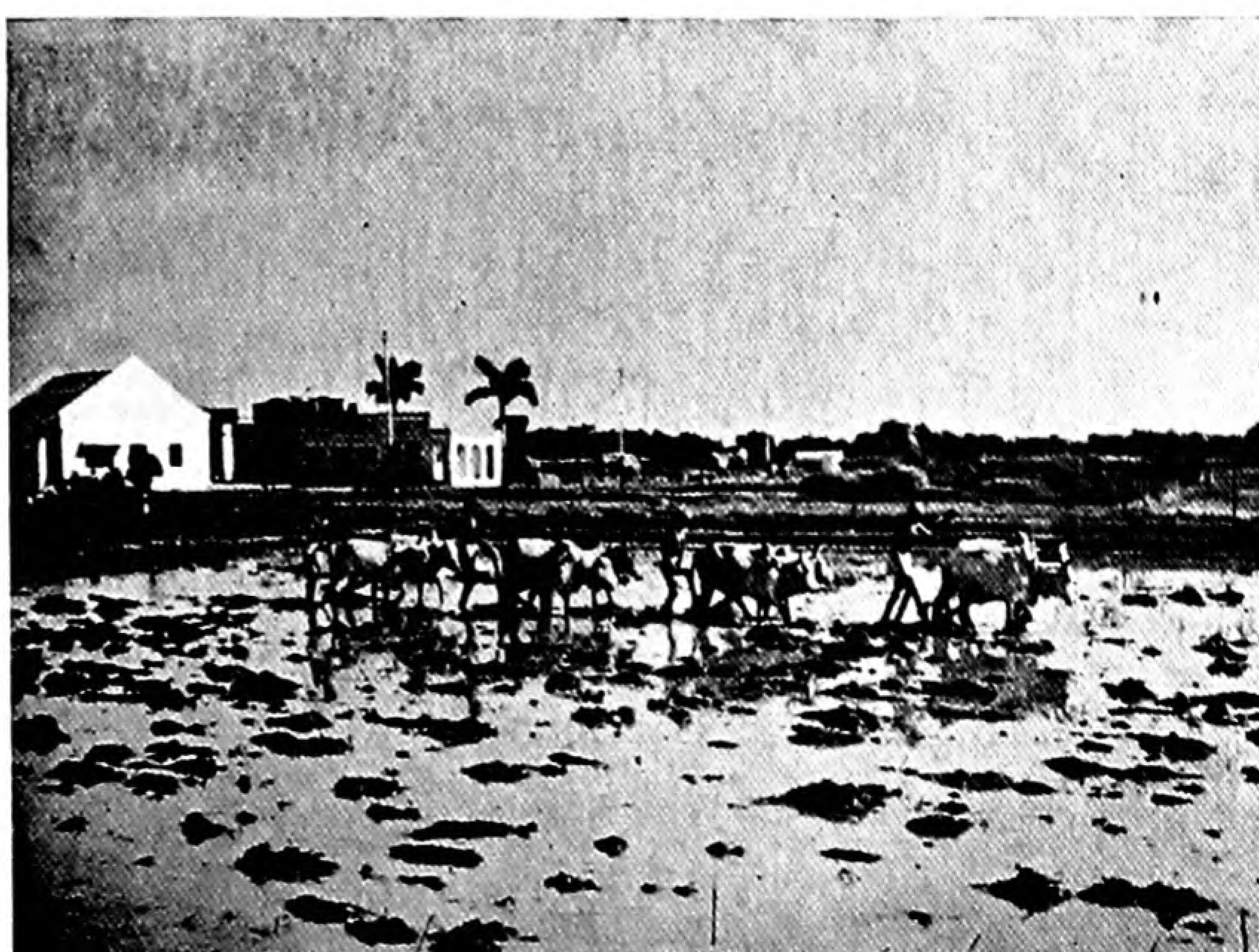


Fig. 11. Burying green manure with a tractor

Fig. 12. Puddling with bullocks



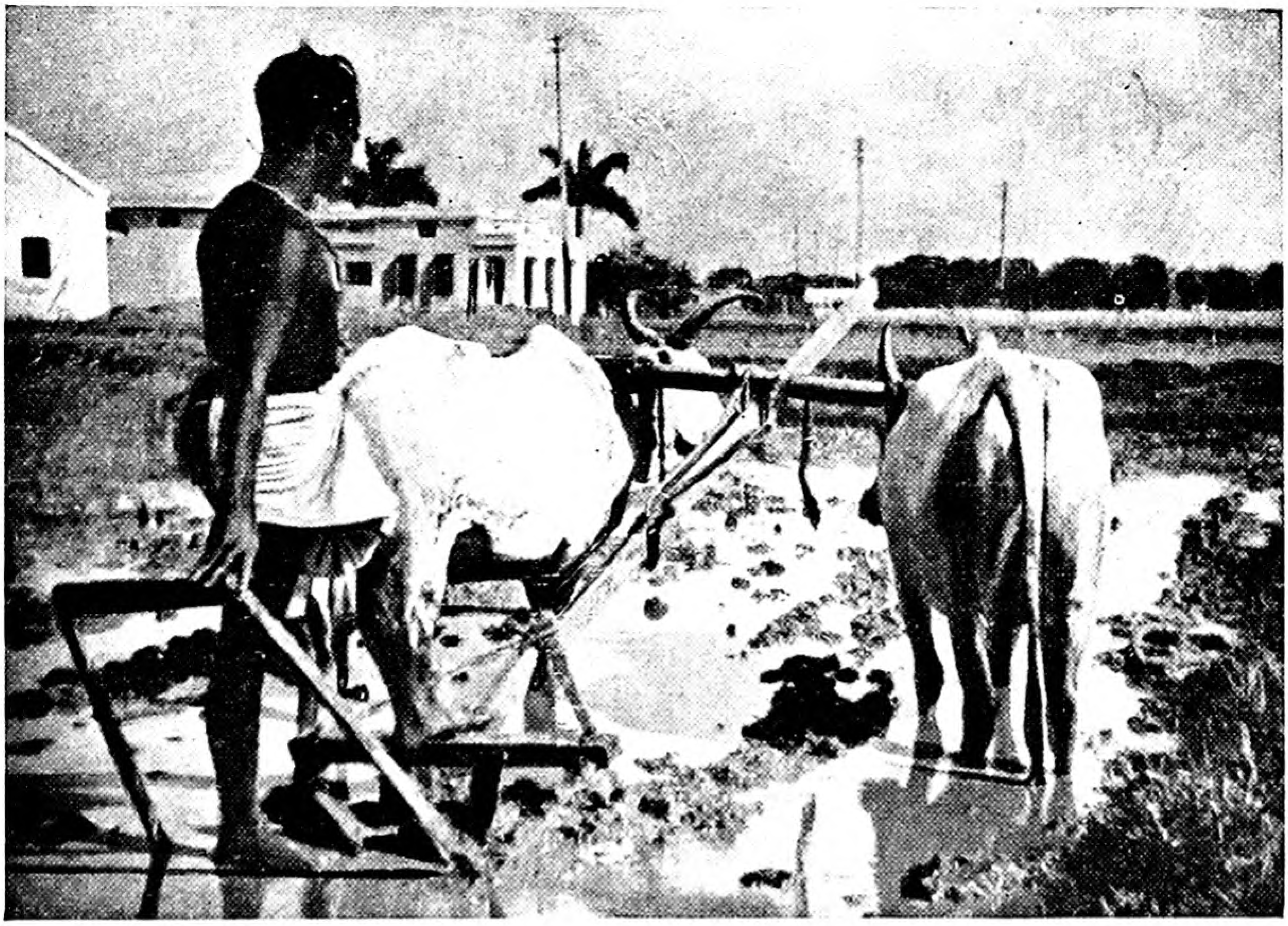


Fig. 13. A wet-land puddler in operation

Fig. 14. Puddling with bullocks

about two inches of standing water in the field and planked, if there are too many weeds. Following the above operation, a partial weeding of the crop, thinning wherever the seedlings are crowded, and simultaneously filling up the gaps with the thinned out seedlings, are done. This practice, known as *beushan* in Orissa, *biasi* in Madhya Pradesh and *hodding* in the Punjab, serves the triple purpose of weeding, thinning and interculturing the crop. The stirring of the soil four to six weeks after sowing promotes root formation, and the thinning of the crop induces better tillering due to the greater spacing between plants. In areas where rice is seeded along with a green manure crop like *dhaincha*, this operation not only serves the purpose of incorporating the green manure crop, but also has been found to reduce straw yield and increase the grain yield by checking the vegetative growth of the crop for a period of about 12 to 18 days. Experiments conducted in Madhya Pradesh and Orissa have shown that *biasi* or *beushan* increased the yield of the crop by 9 to 40 per cent. It was also observed that with long duration varieties, *beushan* gave as good a yield as transplanting.

Sowing Practices. The methods of sowing rice are: (i) broadcasting the seed, and then lightly ploughing the land with a country plough or working the cultivator to cover the seed, (ii) sowing the seed in furrows behind the country plough or dibbling two to three seeds per hill four to nine inches apart in the furrows according to the duration of the variety and (iii) drilling the seed in lines.

BROADCASTING: When the field is in right condition, seed is broadcast. Generally, after covering the seed, a wooden ladder weighted by the ploughman standing on it is passed with a view to compacting the soil, as this induces the subsoil moisture to rise to the surface and accelerate germination. The practice of laddering immediately after sowing is not done in Malabar and South Kanara as due to the heavy rainfall in the area, there is sufficient moisture for the seed to germinate. It may be observed here that if the seeds are soaked for six to eight hours previous to sowing, germination is hastened. This practice is advantageous if the moisture content in the soil is below the optimum required for normal germination. Generally, it takes four days for the seed to germinate. After germination, a ladder is gently passed for about four days with the object of breaking the surface soil crust and smothering the quick-growing grasses. As the plumule is tender and pliable at this stage, it is not damaged by this operation.

DIBBLING: While broadcasting is the most common method of sowing in almost all the States, the practice of dibbling the seed behind furrows in the country plough at regular intervals obtains in some parts of Madras and Bombay States. This method is an improvement over that of broadcasting in that the seed-rate is generally reduced by about 30 per cent. Besides, it has been the experience of the cultivators that the yield obtained from a dibbled crop is, as a rule, better than that from a broadcast one. Another advantage of dibbling is that a uniform germination, resulting in an even stand of the crop is ensured. In a dibbled crop, the interculturing operations and roguing of wild rices are facilitated. It has also been observed that a crop dibbled in lines is able to resist drought better than a broadcast crop, and is more uniform in flowering.

DRILLING: Drilling rice is by far the most common method of sowing in certain parts of Bombay and Mysore State. Of the 77,500 acres under

rice in Saurashtra of Bombay State, more than 97 per cent. is drilled. The distance between the rows is 18 inches, and the intercultural operation is done by bullock-driven implements. Generally, the crop is intercultured four times. In the uplands of some parts of the Circars in Andhra Pradesh, where rice is grown as a 'dry' crop or as mixture with pulses, drilling is adopted, as this enables the cultivator to cover a large area with a few pair of bullocks within a limited sowing period. Drilling has the same advantages as dibbling. Drills which are commonly used for other crops are also used for rice.

THE 'WET' SYSTEM

The 'wet' system is practised where there is an assured and adequate supply of water. In this system, sprouted seed may be directly sown in a puddled and levelled field, or the crop may be transplanted with seedlings raised in a nursery. Of these, transplanting is more common and is adopted wherever water facilities are available. However, the sowing practice adopted depends upon the prevailing soil and climatic conditions and other agronomic factors.

In the 'wet' system, the land is thoroughly ploughed with a country or iron mould-board plough with two to three inches of standing water in the field. Tractors like 'Ferguson' or Caterpillar type like 'Oliver O.C. 23', can also be used for puddling the soil quite satisfactorily. The field is ploughed repeatedly three or four times with an interval of about four days between each ploughing, and levelled before planting. The aim of puddling operation is to get a soft soil with a fairly impervious subsoil, so that the transplanted seedlings can establish quickly and the plant nutrients in the top soil are not washed down too much. It may be mentioned here that puddling is not done in the very heavy soils of the Krishna and Godavari deltas. Planting in these areas is done straightway after letting in water in the field, as the soil crumbles even without ploughing.

Broadcasting in 'old' puddle is usually practised with early varieties in the 'double rice crop' areas in South India, and the yield is reported to be as good as that of a transplanted crop. However, transplanting is advantageous for the following reasons:

1. It enables the cultivator to give a thorough cultivation to the field.

2. The puddling operation, a pre-requisite for planting, buries all kinds of weeds, which otherwise would compete with the rice plant for the nutrients in the soil.

3. The seedlings on transplanting in soft puddle are invigorated, and put forth fresh roots in all directions. The root system is thus extended, and enables the seedling to utilise food material from all round the area.

4. Since the nurseries occupy only 1/10th of the area of the field crop, the cost of irrigation is reduced as compared to a broadcast crop of the same age. Besides, nurseries raised in advance enable the crop to be put in the field at the right time. It also enables the maturing of the crop to be so adjusted as to allow a second crop to be taken.

5. The young crop is often subjected to insect attack, which can be easily and effectively controlled in a seed-bed, whereas any control measures in the case of a broadcast crop would be more expensive.

By far the most important of the advantages is the thorough cultivation which the field receives. This effectively keeps down the weeds, and thus reduces the cost of cultivation.

In the 'wet' system of cultivation, the preparation of seed-beds, the different methods of raising seedlings, the optimum age of seedlings, the optimum spacing and the number of seedlings per hill, and the optimum time of planting are the chief factors that largely influence the yield of the crop.

Preparation of Seed-beds. There are three methods of raising seed-beds—(i) dry, (ii) semi-dry and (iii) wet. All the three are adopted in the different rice tracts. The dry seed-bed is raised in the rice areas where irrigation facilities are lacking, but rainfall is adequate and the soil is of friable texture. The semi-dry nursery is sown as a dry seed-bed, and later flooded and treated as a wet nursery. It is commonly adopted in the southern districts of Madras. The practice of raising a wet seed-bed is prevalent in Andhra Pradesh and Madras. However, dry seed-beds are raised in these States in areas which do not have an assured water supply. The wet seed-bed is the best method of obtaining well-grown seedlings within a short period for planting in the right season. While such a seed-bed is decidedly useful for tracts with an assured supply of water for early planting, the dry seed-bed is useful in places where the time of receipt of water for the transplanting is uncertain, and seedlings have to be kept ready so that immediately on receipt of water transplanting may be done. Seedlings raised in a dry seed-bed are hardier and can withstand adverse conditions better than those of a wet seed-bed. Seedlings in the dry seed-bed can also be kept for a longer period than is usually allowed for a variety without formation of nodes, by cutting off irrigation water. In the case of a wet seed-bed, it cannot be allowed to dry up without serious damage to the seedlings. The preparation of wet and dry seed-beds is described below.

WET SEED-BED: The seed-bed area is ploughed twice, either under dry or wet conditions, and then puddled by giving two or three more ploughings. Care is taken to see that a film of water is always kept in the field, and that it does not dry up. After ten days, the field is again ploughed twice and levelled. Usually, well-decomposed cattle manure or compost at the rate of eight to ten tons per acre is applied at the time of the last ploughing. If green leaf is available, it is applied at the rate of 10,000 lb. per acre just after the second ploughing and buried in the soil. When the leaves have decomposed in about three weeks' time, the field is repeatedly ploughed to bring the soil into a soft puddle. Under the conditions obtaining in India, heavy fertilization of the seed-bed is not necessary, as this practice does not affect the yield of the crop. However, where seedlings are required quickly for planting, such a fertilization of the seed-bed may be resorted to.

When the field is brought to a fine soft puddle, it is divided into small raised beds, 4 feet wide, and of convenient length, with a 1½ foot wide channel all round to facilitate drainage and even sowing of seed. The loose soil from the demarcated channel is taken out to a depth of about nine inches, and thrown on either side of beds, thus raising the beds slightly. The beds are now thoroughly levelled, and one to two inches of water is allowed to stand in the bed. This helps the colloidal particles to settle down, leaving the water clear so that the soil can be seen, and sowing done uniformly. Sprouted seeds are used for sowing a wet seed-bed.

Next day, the water in the seed-bed is completely drained off. If rain is expected, it is advisable to postpone the draining of the nursery, as otherwise the rain will sweep the seeds to one side and also bury the seed in the soil. This would result in an unsatisfactory germination and uneven stand and growth. If water accumulates in small pockets in the bed, it is gently drained away into channels, as otherwise the seeds lying in the pocket may rot. After three or four days, depending upon the physical texture of the soil, when fine cracks are forming, the nursery is irrigated lightly. This is continued until the seedlings are about two inches tall, and thereafter, about half an inch of water is maintained in the bed, but is frequently changed.

A top-dressing with 50 to 100 lb. of ammonium sulphate per acre is given, if the growth of the seedlings is not satisfactory.

Seedlings raised in 8 cents of seed-bed with 24 lb. of seed in the case of medium or fine varieties, or 32 lb. in the case of coarse varieties, is sufficient to transplant an acre of land. The seed required for sowing the nursery is loosely packed in a gunny bag, and soaked in water for 16 to 20 hours. The bag is then completely drained and kept in a dark place, covered with couple of wet gunny bags to ensure optimum conditions for germination. The seeds germinate 24 hours after soaking. Sprouted seeds when sown get established quickly, and a uniform stand is obtained in the seed-bed.

In Andhra Pradesh, in the central and eastern portions of the Godavari Delta, the second rice crop, which is planted between the middle of January to the first week of February suffers from lack of irrigation water during the maturing phase. For such areas, a special system of raising seedlings for the crop is advocated by the Maruteru Rice Research Station. The seed-bed is prepared, sown and treated like a wet nursery for about three weeks. When the seedlings are eight to ten inches tall, the water supply is cut off and the seed-bed allowed to dry ; the seedlings wither and appear as if scorched. These seedlings are uprooted dry, and prior to planting are kept in a puddled plot for 24 to 36 hours, by which time they root profusely. Thus treated, the seedlings establish quickly, and the crop matures ten days earlier than usual, and thus escapes the drought period.

Dry seed-bed: The field selected for the seed-bed is brought to a fine tilth by repeated ploughings and laddering. Eight to ten tons of well-decomposed cattle manure or compost, or eight to ten maunds of well-powdered groundnut oilcake to an acre is evenly spread and incorporated into the soil.

In Bombay State, where the soil is sticky and hard, the *rab* system of preparing the seed-bed prevails. This practice consists in covering the seed-bed with cow-dung and other available organic refuse or brushwood and burning the same. This practice, besides fertilizing the seed-bed, creates a friable top layer which facilitates germination and stimulates the growth of the seedlings. The *rab* method of preparing seed-beds has been found to be a wasteful practice, and in its place fertilizing the seed-bed at the rate of 40 cartloads of compost or farmyard manure and 200 to 300 lb. of ammonium sulphate is being advocated.

Seed is sown broadcast at the rate of 4 lb. to a cent for a coarse-grained variety, and 3 lb. for a fine variety. After sowing a light country plough is worked in the seed-bed, followed by laddering to cover the seeds. If it is found necessary,

laddering is done for two days consecutively for compacting the soil and stimulating germination. After germination, a very light irrigation is given once in three or four days, depending upon the nature of the soil.

Transplanting. The seedlings are uprooted at the optimum age (three to four weeks for rices of three to four months' duration, and five to six weeks for long duration varieties of five to six months), and planted in the puddled field on the same or the next day, as it is not desirable to keep the uprooted seedlings longer. In the case of short rices, the seedlings are closely planted (4×4 inches or 6×6 inches) with two seedlings per hill, but with long duration varieties, the planting is done with a wide spacing of 12×6 inches with three to four seedlings per hill. In rich soils, however, for long duration varieties a wider spacing of 12×12 inches with four to five seedlings per hill is adopted. But under late planted conditions, a close spacing is always given to compensate for the smaller number of tillers due to the shorter period of vegetative growth.

The time of planting has a profound effect on the yield of rice. Planting early in the season is conducive to higher yields. However, to a large extent, the time of planting is determined by the outbreak of the monsoon. Planting in the first week of June has been found to give the best out-turn of the crop in Uttar Pradesh, the Punjab and Kashmir, while the best period for planting the *aman* crop in Orissa, Bengal, Assam and Bihar is from the middle of June to the end of July. However, certain varieties under favourable seasonal conditions, can stand planting up to the first week of August. For planting the *boro* crop in Assam, the last week of December is the best period.

In Bombay, South Kanara and northern parts of Malabar, June is the ideal period for planting the first crop. In South India, for the deltaic area of the Cauvery and the Valley of Vaigai and Tambraparni, the best period of planting for the first crop is from the middle of June to the first week of July, while for the second crop, the second and third weeks of October are the best. However, for certain second crop varieties, the time of planting can be extended up to November-December. For the deltas of the rivers Godavari and Krishna, the best period of planting is during June for the first crop, and the last week of January to the first week of February for the second or *dalua* crop.

Double Transplanting. The practice of double transplanting is prevalent in some tracts of Andhra Pradesh, Madras, Bombay, Uttar Pradesh and Assam. In this method, seed is sown in the nursery as usual, and when the seedlings are 30 to 40 days old, they are transplanted in bunches with a close spacing in a second nursery. The seedlings are retransplanted after about a month in the field with the usual spacing. Double transplanting is adopted where timely planting in the field is not possible for lack of water facilities, in places where an early planting results in too rank a vegetative growth due to the high fertility of the soil, and in places where it is desired to hasten the flowering of the crop for early harvesting. Double planting is an expediency to counteract the deleterious effect of planting late in the season or planting aged seedlings. This practice effects economy in the seed requirements. At the Research Station at Samalkot in Andhra Pradesh, it has been found that 10 lb. of seed is sufficient for transplanting an acre under the method of double transplantation, while 25 lb. is required for single transplanting.

Under Assam conditions, double transplantation, either in low or high lands, has been found to hasten the maturity of the crop, and the yield obtained is higher than the late planted crop.

AFTER-CARE OF THE CROP

Irrigation. The first and foremost care to be taken after planting is the maintenance of optimum water level in the field. This is done either by impounding the rain water or by irrigation, according to the prevailing conditions in the area. As a rule, transplanting is done with about half to one inch of water in the field. This low level of water is maintained for about a fortnight, till the seedlings are established, and thereafter the level of water is increased to 2 to 3 inches, till the grains pass the dough stage. About a week before harvesting the crop, the field is completely drained off. The time at which this draining is done depends upon the properties of the soil. In porous and light soils, which have a lower moisture retaining capacity, irrigation is continued till the crop is almost ready for harvest. In a heavy soil, however, irrigation is cut off a week to 10 days before harvesting. In almost all the canal irrigated areas, the above irrigation practice is adopted, excepting in Bihar, where the practice of completely draining off the field a month and a half after transplanting, i.e., in the middle of September, keeping it dry for about a fortnight, and then flooding it, is in vogue. This practice is called *nigar* and is undertaken with a view to allowing the land to form cracks for a few days, in the belief that this would result in better yield.

Manuring. Though in importance manuring comes next to water, till recently, the practice of manuring of rice fields was hardly followed by cultivators except for the application of a small quantity of available farmyard manure. However, as a result of Extension work in popularising manures and manuring, cultivators are now getting fertilizer-conscious and the use of chemical fertilizers like ammonium sulphate and the practice of green manuring are becoming increasingly popular.

At present, about 20 cartloads of farmyard manure or compost is given as a basal dressing before planting, or green manuring done, usually with *dhaincha* (*Sesbania aculeata*), at about 5,000 to 6,000 lb. of green matter per acre. The green manure crop is usually grown *in situ* two months prior to planting, and ploughed in about a week before the crop is transplanted.

The use of 100 to 150 lb. of bonemeal or superphosphate, in conjunction with green manuring or farmyard manure is being advocated. Besides the basal dressing, fertilizing the crop with 100 to 200 lb. of ammonium sulphate as a top-dressing is also being recommended.

Weeding and Interculturing. Weeding, an important cultural operation for rice, is often ignored by the cultivators. Usually, a greater weed infestation is seen in the broadcast crop than in the transplanted crop. Weeding is usually done by hand. In the dry land broadcast crop, however, a tined harrow, locally called *bidha* is passed through the field, while in a transplanted crop, two to three hand weedings are usually given at intervals of 20 days. As the weeds are removed and buried, the soil round the plants is also stirred. Planting the crop in lines and weeding the crop with a Japanese rotary weeder are now being advocated. In

the 'semi-dry' system of cultivation, where rice is sown as a dry crop and treated as a wet crop later, *beushan* or *biasi* is done with a *desi* plough for the weeding and interculturing of the crop. This practice of *beushan* has been described earlier.

HARVESTING

The right stage for harvesting rice is when the ear is nearly ripe and the straw has just turned yellow. If the harvesting is delayed till the crop is dead ripe, a loss in grain occurs, due to shedding, and the milling quality of the grain is also affected.

Rice is always harvested by human labour in India. The crop is cut and allowed to dry in the field for three to four days, and then brought to the threshing yard. Threshing is done by treading the sheaves by cattle or by beating the earheads against a hard floor or a wooden plank. The Japanese pedal thresher has been found to be useful and economical for the purpose.

ROTATION

Wet Land Rice. The rotation system of cropping as practised in dry land cultivation is rarely followed in wet land rice cultivation, because of the inadequate control of irrigation and drainage in most of the rice areas. The low-lying paddy lands remain submerged under water for 6 to 8 months during the year, which precludes the possibility of growing any other dry crop side by side with rice, and thus the growing of the rice crop on the same land year after year becomes inevitable. The nature of the rice soil, the method of cultivation and the inadequate supply of irrigation water in the post-South-west Monsoon period also restrict the scope of growing other crops after the harvest of rice. Thus, no systematic rotation in such areas is possible, and one-season cropping with rice is generally practised.

Upland Rice. In upland rice areas, where the soils are well drained and have good moisture retention capacity, a subsidiary crop of a quick-growing legume is grown after the harvest of rice, which matures on the residuary moisture in the soil. The system of growing winter or summer legumes varies according to the soil and climatic conditions. In North India, where the winter temperature is low, mostly gram or pea is grown as a catch crop after the preparation of land on the harvest of the rice crop. Where the land does not come into condition for ploughing, *khesari* (*Lathyrus sativus*) is sown broadcast in the standing crop of rice during the months of October-November. In some areas, red gram (*Cajanus cajan*) is grown mixed with upland or dry rice as a safeguard against the failure of rice due to drought. In south India, there is a practice of growing a catch crop of some legume, i.e., black gram (*Phaseolus mungo*), green gram (*Phaseolus aureus*) or horse gram (*Dolichos biflorus*) after the harvest of the main season rice crop. A mixture of green gram and wild indigo (*Tephrosia purpurea*) is also sown after rice in certain areas in the South. While the green gram is harvested, the latter remains in the field for use as a green manure crop for the succeeding rice crop.

In western India, rice is followed by a subsidiary crop of *val* (*Dolichos lablab*) or black gram.

In Kashmir State, a crop of lentil (*Lens esculentum*) is grown after the harvest of rice. When turned to the soil as green manure crop, it greatly benefits the succeeding crop.

Irrigated Rice. In areas where irrigation is available in the post-South-west Monsoon period, a variety of crops is grown. In North India, *berseem* (*Trifolium alexandrinum*) is grown succeeding the rice crop. This crop, besides giving a high yield of green fodder, increases the succeeding rice crop. In well drained upland rice fields, where the soil is of a light texture, potatoes or vegetable crops are grown after the harvest of rice. In eastern India, in low-lying areas with irrigation facilities in the pre-monsoon period, a crop of jute (*Chorchorus capsularis*), is grown during the months of March-April, followed by rice from July to December. In southern India (Andhra Pradesh), where the winter temperature is not low, double cropping of rice is practised. Usually, a medium or late duration rice variety is grown as a first crop from June to November, and an early duration rice variety from January to April. In recent years, cash crops like groundnut (*Arachis hypogaea*) and cotton are grown in sequence with rice under irrigated conditions.

From the above description it is clear that though no systematic rotation is followed in the rice areas a large variety of legume crops are grown as subsidiary crops which mature on the residuary moisture in the soil. Such practices could be further extended to other areas where a seasonal fallow is the general rule, by introducing suitable varieties of crops and implements for the expeditious preparations of the land after the harvest of rice.

With more irrigation becoming available on the completion of the multi-purpose projects on hand, more profitable crops can be grown in sequence with rice by adopting proper manurial schedules.

SPECIAL METHODS OF RICE CULTIVATION

Besides the three principal systems of rice cultivation described earlier, there are a few special methods of cultivating rice peculiar to certain areas, which are described below.

Cultivation in Saline Areas. A large area of saline lands exists along the coastal regions of Kerala, Orissa, Andhra Pradesh, West Bengal and Bombay States. In Kerala the lands adjoining the backwaters are subject to tides from the sea. They become saline after the North-east Monsoon is over by about January, and remain saline till the South-west Monsoon commences in May-June. Cultivation of these lands starts in February-March. By February, the land is thoroughly drained out through the sluices on the outer *bunds* during the low tide. The soil is then worked up into mounds about three to four feet in diameter and two to three feet high. When the first showers of the South-west Monsoon wash off the salts from these mounds, the top soil of the mounds is stirred, and sprouted seeds sown. After about 40 to 45 days, the rain water in the field is drained out. The mounds are cut up into small bits with a few seedlings in each and distributed evenly throughout the field. The field now comes to its original level and resembles a newly transplanted area. A saline-resistant variety is usually grown in this area, as the soil, in spite of the pre-treatment given to reduce the high salinity, still remains slightly saline.

In the Sundarbans of West Bengal, large areas are inundated by sea water and such areas are being gradually reclaimed by the construction of dykes to prevent

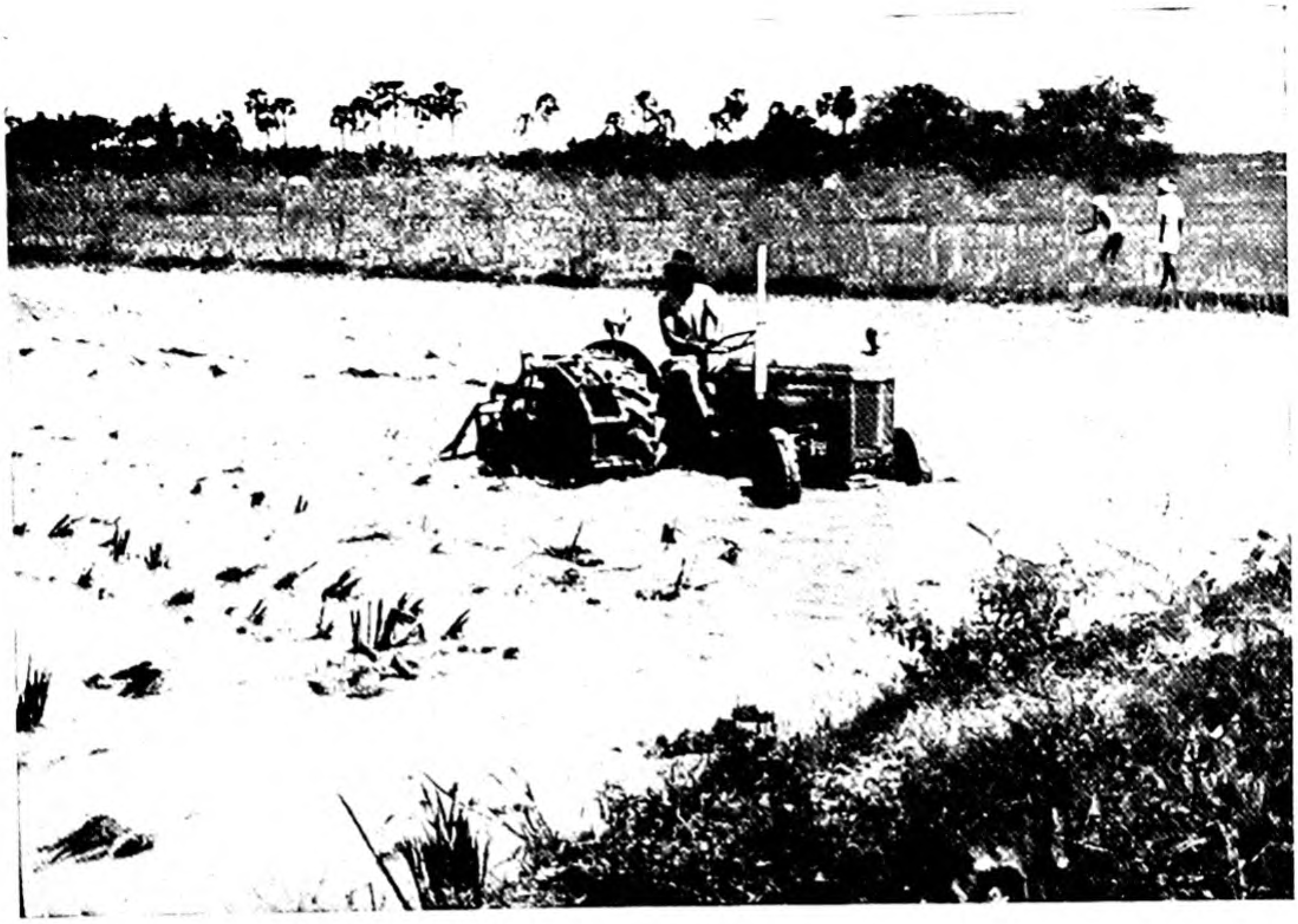


FIG. 15. Puddling with a tractor

FIG. 16. Levelling the puddled field

FIG. 17. Hand-levelling the field

FIG. 18. Uprooting seedlings

FIG. 19. Transporting seedlings

FIG. 20. Transplanting seedlings

Fig. 21. Interculturing with a rotary weeder

Fig. 22. Harvesting rice

the tidal water from entering the fields and by leaching out the salts. Saline-resistant varieties are usually grown in such areas.

In Orissa State, there are small islands with saline soil where rice is cultivated on a co-operative basis. A ring *bund* is constructed around the whole area to check the inundation by saline water and also to conserve rain water. From time to time, the salts are leached out by deep cut drains. In some places, green leaf manuring is done with the leaves of *Tamarindus indica* and *Azadirachta indica*. When the salinity of the soil is brought to a low level, seedlings of saline-resistant varieties, raised in seed-beds outside the saline area, are transplanted. In the first two or three years, the rice crop is poor, but in course of a few more years, these saline lands become fit to support a good crop of rice.

Cultivation of Flood and Deep Water Rices. The rice cultivation in the Kuttanad area of Kerala, is interesting. The rice fields are lowlying, and mostly lie around the Lake Vembanad and on the sides of the rivers. The Lake is in direct communication with the sea at several points, and the water in it and the rivers become very saline by February. The whole area is a vast sheet of water from June to November, and cultivation starts only from November at the cessation of the North-east Monsoon. Ring *bunds* separating the fields from the rivers, canals or lakes are raised and water from within is pumped out by electric power or oil engines. As the water level in the interior sufficiently recedes, the inner *bunds* are repaired, and the fields sown broadcast with sprouted seed at 80 to 100 lb. per acre in about knee-deep water. The water is completely drained out in about three to four days' time. Since the water in the lakes and rivers becomes saline by February, only short duration varieties of 85 to 100 days are grown. Even where there is a standing crop in the field, the water outside stands several feet above the level of the crop. A similar type of cultivation is followed in parts of South Malabar and is called *cole* cultivation.

In the low-lying tracts of the Brahmaputra and Surma valleys in Assam, floods occur regularly, and in these areas deep water rices are commonly grown. Depending upon the depth of water, either deep water *aman* or *assra* (shallow-water winter rice) is grown. These are usually sown broadcast between March and May with the first showers. The plants are firmly established by the time the flood water rises, which usually reaches its peak by July-August and begins to recede by October. Deep water rices grown under such conditions have the capacity to elongate rapidly and keep pace with the rise of the flood water.

In Orissa, the *dalua* crop, and in West Bengal the *boro* crop, are grown in the low-lying flooded areas. The cultivation of these crops starts in November-December as and when the flood water recedes. The land is puddled and planted with seedlings of short or medium duration varieties. The crop is irrigated as and when required from the very low-lying areas which remain under water.

Udu or Mixed Cultivation. This method, which consists in growing two varieties of different durations mixed together, is practised in the very low-lying areas of the Cauvery delta of Madras State, in some parts of Kerala and in some low-lying areas in Assam.

In Madras, this system is called *udu* cultivation. The low-lying areas of the Cauvery delta are deep alluvial in nature, subject to inundation by the North-east

Monsoon rains in October-November. In this method, seedlings of a short duration (100 days) and long duration varieties (210 days) mixed in the ratio of 3 :1 or 4 :1 are raised in seed-beds and planted at random in the month of June with a spacing of nine inches between plants and with five to six seedlings per hill. When the short duration variety matures in the month of September, the long duration variety is still in the vegetative phase. While harvesting the short duration variety, which is not cut close to the ground, the long duration variety receives a topping, which induces profuse tillering. Subsequently, a raking is given to bury the stubbles of the early variety. The long duration variety which is treated as a second crop, is harvested in January. In these areas, the growing of a second crop of rice is otherwise not possible in October-November, as the land is generally inundated due to the rains from the North-east Monsoon, and the soil being deep alluvium, cannot be puddled as the animals would sink knee-deep in the field. As the soil is amenable to agricultural operations only in the month of June, the *udu* method of cultivation is practised.

Mixed cropping of rice varieties is practised in Kerala and in Assam, as an insurance against the vagaries of monsoon. In Kerala the seeds of *viruppu* (short duration variety) and *mundakan* (long duration variety) are sown mixed together at the beginning of the South-west Monsoon. The *viruppu* variety is ready for harvest in August-September and the ears alone are harvested. The *mundakan* variety, which is allowed to grow as a second crop, is ready for harvest in October-November.

In Assam, seed of *ahu* (short duration variety) and *bao* (long duration variety) are sown mixed together in March-April. The *ahu* is harvested in June-July and *bao* in December. By this method, some yield is ensured from one or the other of the crops.

Podu or Shifting Cultivation. This type of cultivation is a primitive method of raising the crop, and is still in vogue with the hill tribes in the mountainous and hilly parts of Kerala, Orissa, Assam and Andhra Pradesh.

The hill tribes in Orissa burn the forest on the hill slopes, work up the land with hand tools, and sow broadcast short duration rice, which is harvested by the end of September. After three or four years, they abandon the site and shift the cultivation to another hill slope. Because of the destruction of the forest by such a cultivation it is being discouraged by the Government.

In Kerala State also, the hill tribes in the Western Ghats practise shifting cultivation, but this however, is being put an end to by the Government, and the terrace cultivation advocated for those regions. Terraced fields of rice are found in India on the hill slopes of Mysore, Assam, Kashmir and Uttar Pradesh.

In Assam the practice of shifting cultivation, known as *jhum*, consists in cutting down the trees in the jungles along the hill slopes in December-January, and setting fire to the dried jungle during February-March. The ashes form the only manure given to the land. The hill tribes do not have any special agricultural implements and only use a knife, known as *daw*, for all field operations. They dig a hole with the *daw* at short intervals, where they sow a mixed crop of rice, vegetables of all descriptions, maize, etc. The different crops are harvested as they mature. This cropping system is practised in the same plot

for two years only and is then shifted to a new plot. The tribesmen come back to the first plot after ten years.

Cultivation of Deep Water or Floating Rices. In parts of Assam and West Bengal, deep water rices are grown in 15 to 20 feet of water. In the very low-lying areas, special floating varieties of rice are sown broadcast with the pre-monsoon rains. As the level of water in the field rises gradually these varieties grow, keeping pace with the rise in the level of water. The ears of the crop are harvested from boats, since the level of the water in the field remains high till harvest.

IMPLEMENTS AND MACHINERY FOR RICE CULTIVATION

For rice cultivation in India, very few implements are used. The rice farmer normally uses an all-purpose wooden plough for the preparation of land, a light levelling board or a ladder, a sickle for harvesting and a spade for digging. Under the present agrarian conditions in the country, the fragmentation of land in small holdings, the poor economic condition of the cultivators and the traditional methods of cultivation in vogue, a complete mechanization of rice cultivation as practised in some of the western countries, is not possible. However, there is great scope for improvement of the existing implements and for the introduction of small manual or power-operated machines for carrying out the agricultural operations more efficiently and expeditiously.

A brief description of some of the indigenous and introduced implements, used in different parts of the country for rice cultivation, is given below.

Desi or Indigenous Plough. A wooden plough is used all over the country for the preparation of land. It is of a common design, with a wooden bottom having a pointed steel share and a handle. The plough bottom is connected through a a wooden beam to the yoke . The body of the plough is made of any hard wood, preferably *babool* (*Acacia arabica*) and is usually made by the village artisans. It makes 'V' shaped furrows, going to a depth of two to three inches without inverting the soil. The plough used for wet cultivation is lighter and smaller than the one used for dry cultivtion, and there is great variation in the size and weight of the plough used in different rice-growing areas. Usually, the plough used in the heavy soils of the deltaic areas is lighter and smaller than the one used in the light soils of lateritic origin, because (1) the heavy soils offer greater resistance to ploughing than the light soils, (2) the animals find it more difficult to move in heavy soils and (3) the animals in the wet areas are generally poor in build. However, in many rice tracts, ploughs of a bigger size commonly used for dry land cultivation are used for the initial opening of the wet lands under conditions of optimum moisture. An ideal puddle for planting is obtained by ploughing the land six to eight times. A narrow wooden plough is used for the operation of *beushan* or *biasi*, and also for covering the seed sown under the dry system of rice cultivation.

In Orissa State, a wide based 'duck foot' type plough is used. This plough is shallow, and due to its wide base, the puddling is done better and a greater area is covered with it than with other indigenous ploughs. Due to its higher turnover, ease in working and ability to puddle well, it is recommended for rice tracts.

Mould-board Plough. Iron mould-board ploughs are now commonly used. These ploughs, besides cutting the soil, also invert it. A number of small mould-

board ploughs like 'Cooper No. 11' and '25', 'Meston' and 'Monsoon' are available, and can be worked by a pair of bullocks. For the initial opening of land and for wet condition, the mould-board plough is well-suited, and it buries the weeds and stubbles of the previous crop. Besides, the turnover of work is also more, and the execution of work thorough and perfect. Two ploughings with a mould-board plough may be considered equivalent to four with a wooden plough in respect of quality of ploughing and puddling of the soil. However, in very heavy clay soils, the mould-board plough is not suitable for puddling operations, as it is likely to sink into such soils.

Wet Land Puddler. The Wet Land Puddler is a very useful, economical and labour-saving implement for producing a fine puddle in wet land. This implement is used only after the land has been ploughed two or three times. It consists of three angular-bladed cast iron hubs rigidly fixed to a hollow horizontal pipe which rotates when drawn by a pair of bullocks. The diagonally set blades churn up the soil, break up clods and create a good puddle. For satisfactory working, the puddler has to be operated with about three inches of water in the field. When the implement is needed to go a little deeper into the soil, the operator has to ride on its wooden frame. This implement works efficiently in all types of soil, except in very heavy clay soils. In a normal eight-hour working, this implement can cover an area of about three acres.

Burmese Satoon. This implement was introduced from Burma into Madras State by Dr. K. Ramiah, and has been modified to suit local conditions. It consists of a rotating axle of a galvanised pipe to which are fixed eight horizontal iron blades and this axle is fitted in a frame with wooden block bearings. A pair of medium-sized animals can work this implement. It is worked after a course of two ploughings for creating a fine puddle quickly. As the implement works, the rotating blades churn the soil and bury the stubbles of the previous crop. In a working day of eight hours, the implement can cover about three acres.

Green Manure Trampler. This is a light implement used for burying green manure in puddle. It consists of four steel discs 10 inches in diameter, with cast iron hubs, rigidly mounted on a horizontal pipe shaft rotating in wooden block bearings. It can be worked by a pair of animals. In a day of eight hours, an area of about three acres can be covered.

Levelling Board. This is a useful implement which serves the important purpose of levelling the field. There are three kinds of levelling boards: (1) a flat, heavy plank with a handle attached in the centre, and secured to the yoke by ropes passing through iron rings provided at either end of the board, (2) a beam with a 'V' shaped groove cut deep into it, without a handle, and secured to the yoke through rings fixed on the top side of the board at either end, and (3) a *moi* or ladder, consisting of two equal-sized planks joined together by wooden cross-pieces with a space of about four inches between the two planks. The *moi* is attached to the yoke by ropes or chains.

These levelling boards are useful in the levelling of the puddled soil evenly so that irrigation or drainage is made easy.

Bidha or Tined Harrow. This is a type of cultivator commonly used for interculturing a dry-sown crop of rice. It consists of a wooden headpiece about

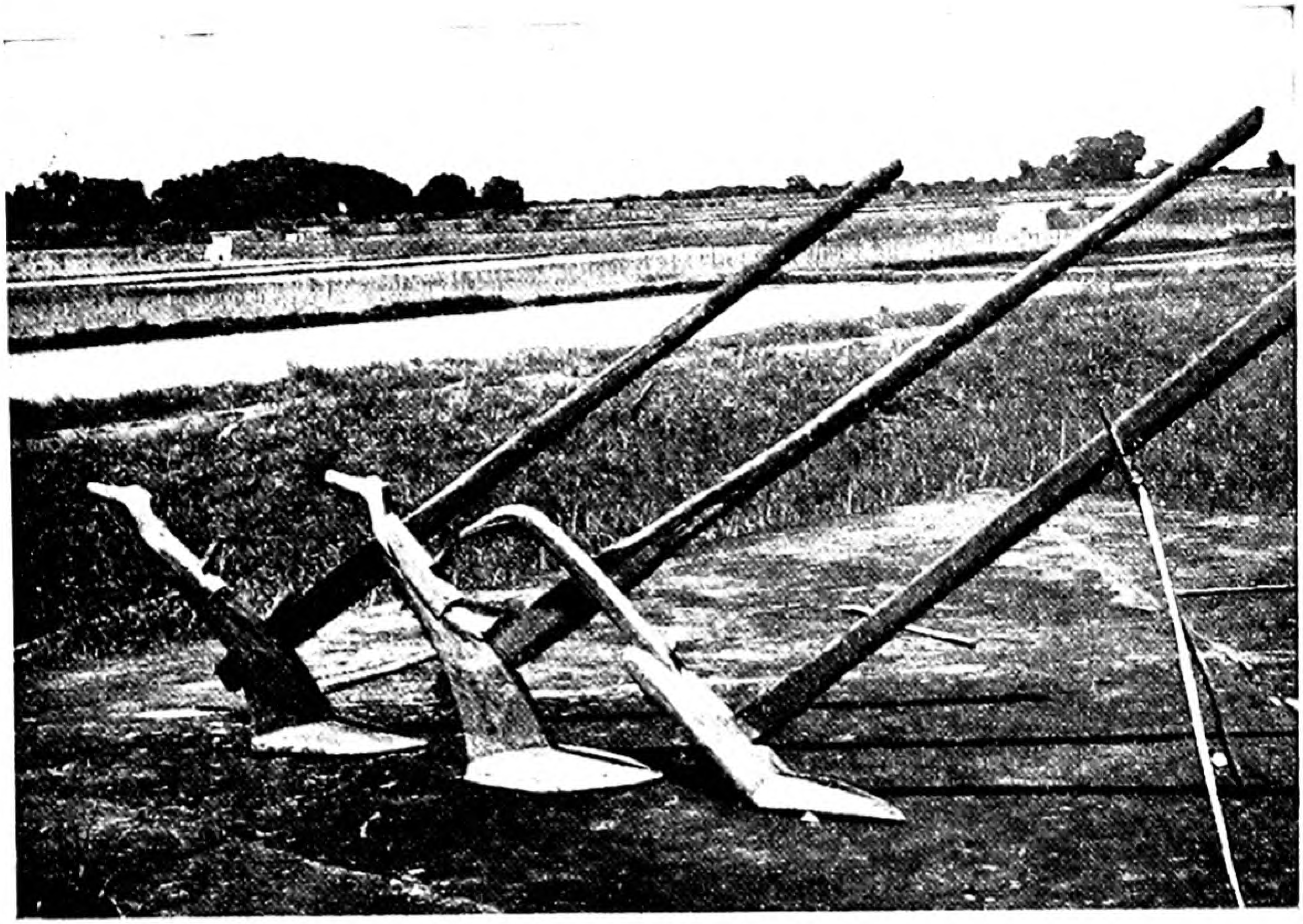


FIG. 23. *Desi* ploughs (centre: a duck-foot plough)

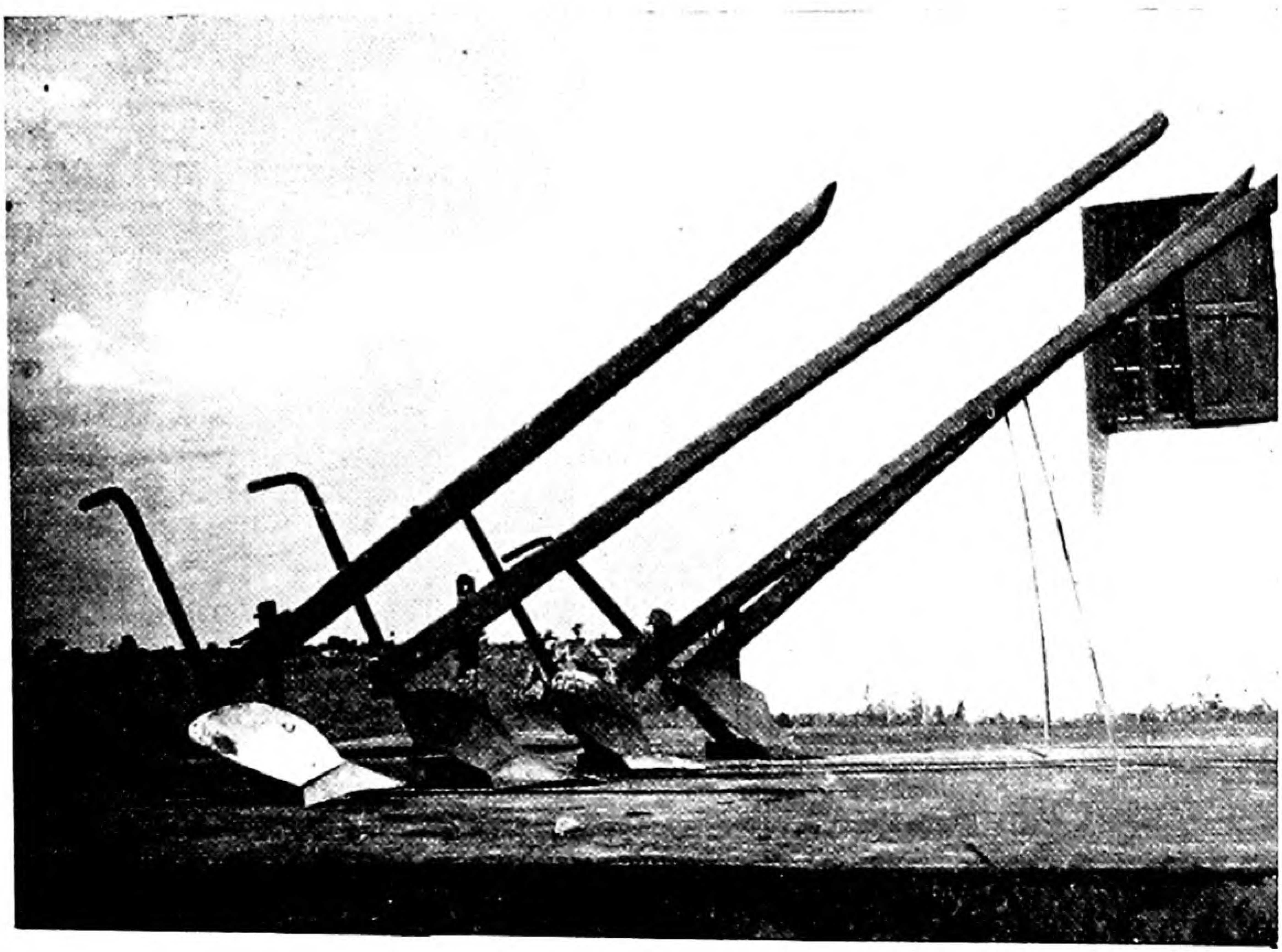


FIG. 24. Mould-board ploughs

FIG. 29. A pedal thresher

FIG. 30. A tractor fitted with an extension wheel

five feet long, with 10 to 12 pointed pegs, a beam and a handle fixed to it. This implement is worked a few days after sowing the broadcast crop with the object of weeding. In the process of working the implement, not only grasses, but young rice seedlings also are disturbed and uprooted, and to meet this contingency, a heavy seed-rate is usually adopted.

Cultivator. This implement is useful for tracts where summer or winter ploughing is done. After two or three ploughings, the cultivator is worked for obtaining a good tilth. The implement has five tines adjustable to various widths, and can cover two acres in a day of eight hours' work. The implement is also used in the place of the country plough for covering the broadcast seed as it can cover a large area.

Blade-harrow or Guntaka or Bakhar. This consists of a heavy beam with an iron blade, and is generally used for intercultivation of dry crops sown in lines. This is also used for preparation of seed-bed, loosening the top soil, breaking clods and covering seeds.

Seed-drills. Indigenous seed-drills in India are known by several local names in different parts of the country. A seed-drill is worked by a pair of animals. The seed is fed by hand through a circular wooden feed-cup connected to the tines of the drill by bamboo or tin tubes. A seed-drill can cover an area of about three acres in a working day of eight hours.

Rotary Paddy Weeder. This implement, recently introduced from Japan, has been found to be efficient and labour-saving. It consists of two sets of revolving curved teeth, arranged in tandem and mounted inside an iron sled. It is suitable for interculturing a rice crop transplanted in lines. Besides removing and burying the weeds, it stirs up the soil also. It is usually worked three to four times at intervals of a fortnight till about a month before flowering. An area of about half an acre can be intercultured in a day of eight hours. Rotary paddy weeders are now being manufactured in India.

Japanese Pedal Thresher. The Japanese pedal-operated threshing machine is a simple and time-saving appliance for threshing paddy. It is light in weight and simple in construction. It has a drum fitted with hardened steel spring-wire and is driven by a pedal. When the ear-heads of paddy sheaves are held on the revolving drum of the thresher, the grains get separated easily. A pedal arrangement with gear and pinions allows one man to operate the machine and also to hold the sheaves. The out-turn per day is 8 to 10 maunds. It is easy to operate, can be conveniently shifted from field to field, occupies a small space and can be worked even in a small enclosure in a cultivator's hut during inclement weather conditions. A pedal thresher on the model of the Japanese thresher is now manufactured in India under the name "Akshat."

Another power-operated threshing-cum-winnowing machine, Tiyado, obtained from Japan, is also found to be satisfactory. Like the pedal thresher, it also has a cylinder or threshing drum fitted with spring wire staples of hardened steel and is operated by 1 to 2 H.P. electric motor. It is operated by two persons. Its output is about 21 to 22 maunds of clean paddy per day of 8 hours.

Tractors in Rice Farming. Of late, the use of the tractor in the reclamation of land has become popular in India. There is a special Central Tractor Organi-

zation under the Ministry of Food and Agriculture, which operates a fleet of heavy tractors in various States for the development of new land and for the reclamation of *kans* (*Saccharum spontaneum*) affected areas. A number of States also have organisations for the reclamation of waste lands such as the *terai* area in Uttar Pradesh.

Light tractor (25 to 30 H.P.) are getting popular for the initial preparation of dry land. Due to lack of moisture, the land gets hard and cannot be ploughed with bullock-drawn implements. The land, therefore, is left uncultivated till the arrival of the rains in the beginning of the sowing season, when the cultivator is hard pressed with various operations connected with the seeding or transplanting of the rice crop. Therefore, the land does not receive proper preparatory tillage, which results in low yields. Light tractors have been found useful for an expeditious and thorough preparation of such land. Tractors with rubber tyres and fitted with hydraulic arrangements are suitable for ploughing fields even as small as 1/5th of an acre without disturbing the field *bunds*.

For rice cultivation, the tractor has to work in wet land and in about a foot deep mud. For this purpose, specially designed wheel extensions are provided for the 'Ferguson' tractor, which prevent the sinking of the tractor in the puddle. The extensions consist of skeleton wheels made of welded steel, which can be fitted on to a standard tractor wheel and are easily detachable. Water-proof brake linings are also provided, so that the brakes work even when fully immersed in water.

For puddling, a specially designed implement is attached to the 'Ferguson' tractor. This consists of cut-away disc harrow with adjustable disc scrapers mounted on the frame, at the back of which are placed levelling boards. The field to be puddled is initially disc-harrowed twice with 9 to 12 inches of standings water, and after a week it is again disc-harrowed once or twice depending upon the condition of the land. The field is then levelled and is ready for planting. In a day of eight hours, the tractor can disc-harrow about eight acres.

CHAPTER 7

DISEASES

Like all cultivated crops, rice also suffers from a number of diseases, some of which cause considerable damage to the crop. It may be said that every year, approximately 10 to 15 per cent. loss in yield is caused by the more important rice diseases, but in years of epidemics, the damage caused in the affected regions may range from 50 to 90 per cent.

Most of the serious diseases of rice in India are caused by fungi, the more important ones amongst these being Blast, Helminthosporiose, Stem Rot and Foot Rot. Several other minor maladies are also caused by different fungi. A list of fungi reported on rice in India is given in Appendix II. Recently, a bacterial leaf disease has been noticed in Bombay and Cuttack. Diseases caused by virus are not known to occur in India. Nematodes cause the *Ufra* disease in West Bengal, Uttar Pradesh and Hyderabad. A peculiar physiological unbalance affecting primarily the root system, has been noticed in many parts of the country. A disease due to copper deficiency has been reported from Bombay and Mysore.

BLAST DISEASE

This is caused by the fungus *Piricularia oryzae* Cav.

Symptoms. All the aerial plant parts show symptoms of the disease. On the leaves, broadly spindle-shaped spots, with pale ashy centres and brownish red margins are seen. In cases of severe infection, several such spots coalesce and the whole lamina is destroyed. The nodes are blackened. When the node immediately below the ear is thus blackened, the symptom is called ' neck infection '. The infection may be confined to the neck region or the individual branches of the ear may also be infected and turn brown or black. These infected branches often break and fall off, or the whole inflorescence may break off at the ' rotten ' neck, resulting in loss in yield. The grains borne on the ears with infected necks are mostly chaffy.

Loss. The loss in yield is caused mainly by neck infection, and also indirectly by leaf infection. Under conditions favourable for the development of the disease, a loss of 43 per cent. of grain yield has been recorded at Cuttack (Annual Report, Central Rice Research Institute, 1952-53). A total destruction of crop by Blast over large areas has been reported in recent years from Andhra Pradesh, Madras, Kerala, Bombay, Orissa, and Kashmir.

Epidemiology. The disease is considered to be seed-borne, but in India, no definite evidence has been found to show that it is so. Probably some of the grasses like *Panicum repens* and *Digitaria marginata*, which have been proved to be collateral hosts of the pathogen, serve as the source of infection.

The rice plant is most susceptible to the disease (Leaf-Blast) in the tillering stage and also at the heading stage (Neck-Blast).

Besides the susceptible stage of the host, the climatic conditions in a region also determine the period of Blast outbreak. The outbreak occurs as early as in August at Kashmir, becomes generally severe in September-October in Orissa, November in Andhra Pradesh and December-January in Madras. Generally speaking, a high degree of relative humidity, copious dew formation and a range of temperature between 24° to 27°C favour the development of Blast.

High level of nitrogenous fertilization favours the development of Blast. Neither phosphorous nor potash applied either alone or in combination with nitrogen, has any effect on Blast incidence.

Control. For the control of the disease, the following measures are advocated:

1. Growing resistant and moderately resistant varieties ; a list of such varieties available in India is given in Table 9.

TABLE 9. LIST OF VARIETIES RESISTANT OR MODERATELY RESISTANT TO BLAST REPORTED FROM INDIA

Madras	Bombay	Andhra Pradesh	C.R.R.I.
1. *Co*.4*	1. *Antarsal*-67		1. *Bhogiim*
2. *Co*.25*	2. *Antarsal*-90		2. *Sm*.6
3. *Co*.26*	3. *Antarsal*-200	1. *M*-42	3. *Sm*.8
4. *Adt*.25	4. *Mugad*-161		4. *Sm*.9
5. *Tkm*.1	5. *Mugad*-249*		5. *CP*.6
	6. *Mugad*-141		6. *CP*.9
	7. *Mugad*-81		7. *Akp*.8
	8. *Patni*-6		8. *Akp*.9
	9. *Bhadas*-6		9. *Ch*.55
	10. *Bhadas*-79		10. *H*.755
	11. *Krishnasal*-10		11. *S*.67
	12. *Waner*-1		12. *S*.624
	13. *1-B*-12-11		13. *Ptb*.10
	14. *Sathi Dwarf* 44-51		
	15. *Sukhvel* 243-4		

*Found resistant at the Central Rice Research Institute also.

Of the above, *Ch* 55 is from China, *Sm.6*, *Sm.8* and *Sm.9* are from Siam and the rest are of Indian origin.

2. Dipping the leaves of seedlings in a copper fungicide solution (0.25 per cent. metallic copper) at the time of transplanting.

3. Spraying the crop four to five times in a season with copper fungicides, (Bordeaux mixture, 5 : 5 : 50 or a proprietary copper fungicide adjusted to 0.25 per cent. metallic copper) at 75 to 100 gallons per acre. In spraying with low volume nozzles, only 20 gallons of spray fluid per acre need be used.

4. Avoiding excessive use of nitrogenous fertilizers.

5. Suitably adjusting planting dates so that the susceptible stages of the host can skip the peak period of Blast incidence in a locality.

HELMINTHOSPORIUM DISEASE

This is caused by the fungus *Helminthosporium oryzae* Breda de Haan(=*Cochilobolus miyabeanus* (Ito et Kuribayshi) Drechsler ex. Dastur).

Symptoms. The disease infects the leaf, leaf-sheath, node and the grain. Small ellipsoidal to circular brown spots, 2.5 mm.in diameter, with a darker central zone appear on the leaves and leaf sheaths. Larger spots up to 10 mm. × 7 to 8 mm. have also been seen, though rarely. The nodes turn black and bear an abundance of the conidia of the fungus. Under severe infection, neck infection as described under Blast also develops. The grains are severely spotted and appear shrivelled. Apparently healthy grains without any spots also harbour the fungus inside the lemma and palea (Padmanabhan, 1949).

Loss. The disease is widespread in India being very common in Assam, West Bengal, Orissa, Andhra Pradesh and the Central areas of Kerala and Mysore, where a certain amount of loss to the crop is caused by the disease. During 1918-19 season, a total destruction of crop was caused by the disease in the Godavari and Krishna deltas and in 1942 a loss in yield amounting to 50 to 90 per cent. was caused by the disease in Bengal.

Epidemiology. The disease is seed-borne, but primary infection develops only in regions where the soil temperature at sowing time is below 25°C. Two common grasses, (*Echinochloa colona* and *Leersia hexandra*), occuring in rice fields which are reported to be collateral hosts of the fungus, may serve as a source of infection to the crop. Secondary infection developing during the later stages of crop growth, especially during flowering, is responsible for severe outbreaks. The plant itself is very susceptible to the disease at the flowering stage. Late rains or heavy rains followed by flooding and continuous cloudy weather at the ripening stage of the crop are some of the factors favourable for an outbreak of the disease. Crops grown under well-balanced manurial conditions do not appear to suffer seriously from the disease. It is generally confined to the crops raised in comparatively poorer soils, under drought conditions and in soils from which the essential elements have been leached out by heavy rains.

Control. For the control of this disease, the following measures are recommended:

1. Growing of resistant varieties. A list of such varieties in India is given below.

*Ch*3, *Ch*.45, *T* 141, *B am*.10 and *Co* 20.

2. Seed treatment with fungicides at 1/400 by weight.
3. Hot water treatment: Seed soaked for 8 to 12 hours in cold water followed by immersion in hot water at 52°C for 10 minutes or at 54°C for 5 minutes (*Caution*: As varieties differ in their reaction to the hot water treatment, a knowledge of their reaction is necessary before this control measure can be adopted successfully).
4. Application of the total amount of manure in split doses, half at planting, a quarter a month after planting and a quarter at flower initiation.

STEM ROT

This is caused by *Sclerotium oryzae* Cat. (=*Leptosphaeria salvinii* Cat. =*Helminthosporium sigmoideum* Cav.).

Symptoms. The sclerotia which are black, round and of the size of a mustard seed are carried by irrigation water, attach themselves to the leaf-sheaths, germinate and penetrate into the outer leaf-sheaths. This may be seen by a brown-

ing at the point of penetration, and the yellowing of the corresponding leaf. As infection advances, the brownish patch of discoloration enlarges radially as well as above and below, and the sheath begins to rot. Inside the culm, the greyish mycelium of the fungus and numerous sclerotia are found. The culm lodges and breaks off. The affected plants put forth a number of green secondary tillers and the earheads are mostly chaffy.

Loss. The disease occurs in West Bengal, Orissa, Kashmir, the Punjab, Madras, Andhra Pradesh and Coorg in Mysore State from where severe losses due to the disease have been reported. It is reported that in the Punjab it causes a loss of 5 to 10 per cent. in normal years, which goes up to 70 per cent. in epidemic years.

Epidemiology. The sclerotia are very hardy structures. They survive in the old stubble and straw, and are the principal sources of infection. The optimum range of temperature for growth and infection is 27.5° to 30°C. The fungus is also a notable acid-lover, preferring a *p*H of 5.04 to 6.01 for its growth. An excessive application of nitrogenous fertilizer favours the development of the disease, while the application of phosphate in a sufficient amount has the opposite effect.

Control. For the control of the disease, the following measures are advocated :

1. Destruction of affected stubbles and straw by burning.
2. Avoiding irrigation through affected fields.
3. Draining the fields and raking the soil.
4. Judicious application of nitrogen.
5. Cultivation of resistant varieties, a list of which is given below :

Dudshar (Bengal), *Basmati*-370 (Punjab), *Basmati*-3 (Punjab), *Mushkan*-7 (Punjab), *Mushkan*-41 (Punjab) and *Bara*-62 (Punjab).

FOOT ROT

This is caused by *Fusarium moniliforme* Sheld. =(*Gibberella fujikuroi* (Saw.) Wollenw).

Symptoms. In the nursery, infected seedlings become pale thin and lanky, and subsequently collapse and die. In the field, affected plants are easily distinguished as they are much taller than the other plants and come to short blade stage earlier. Adventitious rootlets develop from the 1st, 2nd and 3rd internodes above ground level. The pink bloom of the fungus may be seen on the nodes or on the sheaths of affected plants.

Loss. Losses occur generally in seed-beds due to the death of seedlings.

Epidemiology. The infection is seed-borne ; seedlings can be infected at temperatures from 25° to 30°C, but the characteristic symptoms appear only at 35°C. Application of nitrogenous fertilizer favours the development of the disease, while application of phosphate and potash has no effect.

Control. Seed-treatment with fungicides checks the disease effectively. Organo-mercuric compounds are very effective at 1/400 by weight of seed.

PHYSIOLOGICAL ROOT ROT COMPLEX

This disease described as *Pansukh* from Madhya Pradesh, has also been reported from Bihar, West Bengal and Orissa.

Symptoms. The root system of the rice plant becomes highly attenuated under some unfavourable conditions ; the rootlets are thin and rotten and the hair-like spongy rootlets occurring in healthy root system are totally absent.

The effect of this serious set-back in the root zone is seen in the aerial parts. The crown of the leaves turn yellow, brown, or brownish red, or in some cases, remain green, but stiff and erect. Leaf spot disease develops abundantly on such weakened plants in some countries. The plants remain stunted with a few tillers only and this stunting effect is seen most in the flowering axis. The rachis does not emerge properly out of the boot leaf-sheath, and the flowers get twisted, bent and remain mostly sterile and empty.

Cause. It is generally agreed that the above symptoms develop due to the physiological unbalance caused by a complex set of factors, which are not likely to be identical in all localities. Lack of sufficient aeration and accumulation of reduction products in the root zone, appear to be the chief associated factors.

The disease described as Tip-burn in Bihar and another of the same description reported from Uttar Pradesh, are probably the same as *Pansukh*.

Control. Cultural practices which tend to encourage soil aeration like drainage and flow irrigation, interculturing with weeders, etc., are reported to help the plants to recover.

In large areas affected by Root Rot, plants growing in soils rich in available phosphate have remained comparatively free from Root Rot symptoms. The phosphate has a stimulatory effect on the development of the root system, and therefore, soil amendments to correct phosphate deficiency, if any, will help to keep the disease under check.

The following Indian rice varieties, were found relatively resistant under severe infection in Cuttack: *Ptb.* 10, *N.*136 and *Benibhog*, *Adt.*4 and *Adt.*15. The variety *Bondu* was found resistant in Madhya Pradesh.

MINOR DISEASES

Narrow Brown Leaf Spot. This is caused by *Cercospora oryzae* Miyake.

The disease causes linear leaf lesions, 3-6 mm. in length by 1.5 mm. in breadth. In the U.S.A., physiologic races of the pathogen have been found and the control of the disease is through growing resistant varieties.

Leaf Smut. This is caused by *Entyloma oryzae* H. & P. Sydow.

Small minute black spots (leaden black) are seen on rice leaves, mostly in plants reaching maturity.

Sheath Rot. This is caused by *Corticium sasakii* (Shirai) Matsumoto.

In this disease, ellipsoidal spots, about 10 mm. by 3 to 4 mm., are found on the leaf-sheath with a greyish white centre and dirty brown margin. Sclerotia are found in the leaf-sheath.

Black Smut, Kernel Smut or Bunt. This is caused by *Neovossia horrida* (Tak.) Padwick and A. Khan.

This disease affects individual grains. Such grains contain a black powdery mass of spores with or without a slight development of kernels.

False Smut. This is caused by *Ustilaginoidea virens* (Cke.) Tak.

This is an interesting disease, as it is believed by the cultivators that its appearance predicts a bumper harvest. The ovaries of a few individual grains are transformed into large green, velvety masses. Only a few grains in each ear are usually affected.

Udbatta Disease. This is caused by *Ephelis oryzae* Syd. (=*Balansia oryzae* Nar. and Thirumal).

Instead of the inflorescence, a thin, straight rod emerges from the boot leaf-sheath; the rod is dirty-coloured and is often covered with white mycelium. No grain is formed. Recent reports indicate that the disease is becoming more prevalent on the rice crop grown in slight elevations, as in Jeypore (Orissa), the Deccan and the Mysore plateau.

Ufra. This is caused by a nematode (*Ditylenchus angustus* (Butler) Filipjev).

This disease has been reported from West Bengal and Uttar Pradesh. It becomes prominent in the field just at the bootleaf stage. The plants appear stunted, and the upper leaves turn chlorotic. The leaf-sheaths and the leaves have dark, broad patches of a brownish colour. The ears do not emerge properly or emerge with the flowers in a highly discoloured and twisted condition.

The affected plant parts contain innumerable nematodes.

Control. The worm survives in the seed, in the affected stubbles and in soil. Water-stagnation favours the development of heavy infection. Therefore, burning of old stubbles *in situ* is an important control measure. Sowing of only heavier and plumpy seeds by floating out the lighter seeds in salt water is believed to eliminate a considerable amount of initial source of infection. Hot water treatment (60°C for 10 minutes) is also reported to reduce infection. Water in the rice fields must be kept flowing gently by removing bottlenecks at narrow channels and outlets.

Stackburn Disease. This is caused by *Trichoconis padwickii* Ganguly.

This disease, which causes leaf and grain spots, has been reported from West Bengal, Orissa, Madras and Uttar Pradesh. Leaf spots are large, round to oval, 3 to 9 mm. in diameter, with a dark brown margin and a dull grey centre. Several spots may coalesce, forming irregular elongated patches. Only a few grains in an ear are generally affected. Infected grains have a purplish brown discoloration, with a pale white centre, showing the sclerotia of the fungus. Apparently healthy seeds may also contain the fungus inside the seed coat (Padmanabhan, 1949).

Bacterial Blight. This disease, caused by a bacterial parasite and reported from Bombay, is similar to the *kresek* disease reported from Indonesia. The symptoms appear on the leaves 3 to 4 weeks after transplating. Infected leaves are straw yellow, and start withering from the tips following a crinkling of the leaf-blade along the mid-rib. The infection spreads throuh the vascular system. A similar disease has been noticed at the Central Rice Research Institute for the last three years.

A disease, characterized by brick-red coloration and drying up of leaves, has been reported from the Hyderabad area of Andhra Pradesh (Vaheeduddin 1956, unpublished record) and is attributed to *Curvularia lunata* (Wakker) Boedijn. Grains turn light brown and sometimes the kernels of the affected grains become hard and black. The disease is checked by spraying copper fungicides.

A seedling disease, called Leaf Tip Curl caused by a species of *Helminthosporium*, has also been reported from the Hyderabad area (Vaheeduddin 1956, unpublished record).

CHAPTER 8

PESTS

A large number of insects damaging rice, both in the field and the store, have been recorded in India. The major pests, which cause serious damage, are common to all the rice-growing tracts, while the rest are either minor in importance or have been noted as feeding occasionally on rice. The distribution and importance of the pests in the various States of India are given in Appendix III and a list of stored rice pests and non-insect pests of rice is given in Appendix III b. Snails, crabs and rats also damage rice. The regional distribution of any pest and the magnitude of the damage caused by some depend upon environmental and climatic factors. Under favourable conditions, a minor pest in a certain region may become a serious pest in the same region, or in another region. The distribution of rice pests is facilitated by the vast contiguous areas under rice cultivation. Further, many varieties of rice, which come to maturity on different dates, are grown simultaneously in a region, affording continuous food supply and shelter for the uninterrupted breeding and dispersal of pests. These pests have also alternate hosts in some graminaceous plants on which they either overwinter or continue breeding. The more important pests are given below.

Schoenobius incertulas Wlk.

COMMON NAMES: Rice Borer, Yellow Rice Borer, Paddy Stem Borer.

DISTRIBUTION AND IMPORTANCE: This pest is distributed throughout India and in the Andaman and Nicobar Islands, and is reported to cause 3 to 95 per cent. loss. The loss caused by this pest to the rice crop is valued at about a hundred million rupees annually (Narayanan, 1953a). The pest is prevalent all the year round, and is particularly active in areas under double cropping. This is a serious pest in Andhra Pradesh, Assam, Bihar, Bombay, Kashmir, Kerala, Madhya Pradesh, Madras, Mysore, Orissa and West Bengal and minor in Manipur, the Punjab, Rajasthan and Tripura. The attack starts usually in the late planted monsoon crop and extends to the summer crop, which gets so seriously affected that cultivators are often reluctant to grow a summer crop.

SYMPTOMS, DAMAGE AND HABITS: In the nursery and in the young crop, the presence of dead hearts or the wilting of the central shoots is the characteristic feature of attack by the pest. In the ear stage, the incidence of the pest manifests as 'white ears' with chaffy grains. Depending on the stage of ear formation at the time of attack, ears with ill-formed grains are also seen. Further, not all chaffy ears are due to borer damage. A chaffy ear caused by a stem-borer is easily distinguishable by a small hole at or above the second node from the top, and by the presence of the borer or its excreta inside the stem.

The moths are phototropic and are particularly active at dusk when they mate and oviposit. During the day, they remain on sheaths and the ventral surface of the leaf-blades.

The larvae nibble at the epidermis, and later descend to the base of the stem and bore inside, where they remain feeding and cause damage. They pupate in the stubble below the soil level.

The number of broods or generations in a year varies from three to five, depending upon the meteorological conditions and cultural practices. Three broods in a year have been reported from West Bengal and Hyderabad area of Andhra Pradesh while at Cuttack, two main broods, one during November-December and the other during February-April, are found.

Scirpophaga innotata, Wlk.

COMMON NAMES: Rice Borer, White Rice Moth Borer, White Borer.

DISTRIBUTION AND IMPORTANCE: This is particularly serious in Madras, Orissa, Punjab, and minor in Kerala.

SYMPTOMS AND DAMAGE: Similar to *Schoenobius*.

(*Chilo simplex* Butl.) (*Chilo oryzae.*) (*Chilo oryzae* Flet.) (*Chilo zonellus* Swinh.)

Chilo simplex, Butl.

COMMON NAME: Striped Rice Borers.

DISTRIBUTION AND IMPORTANCE: This is a major pest in Bihar and Orissa, and minor in Andhra Pradesh, Madras, Kerala and Mysore.

SYMPTOMS, DAMAGE AND HABITS: Very similar to *Schoenobius* in causing dead hearts and chaffy grains, but the following features distinguish the attack by *Chilo*.

1. The rice stalk becomes bleached and breaks down.
2. The leaf sheath is nibbled at, and is discoloured.

Often, the larvae congregate on the panicles and nibble at the spikelets making them chaffy. The moths are phototropic. There are usually two generations in a year (Logothetis, 1951).

Sesamia inferens, Wlk.

COMMON NAMES: Pink Borer, *Ragi* Stem Borer.

DISTRIBUTION AND IMPORTANCE: This is a major pest in Andhra Pradesh and Madras, and minor in Madhya Pradesh, Uttar Pradesh, Orissa, the Punjab, Mysore, West Bengal and Bihar.

SYMPTOMS, DAMAGE AND HABITS: Similar to those of *Schoenobius*.

Larvae on hatching, first feed on the leaf-sheath and later bore into the stem, attacking specially the thicker stalks. Pupation occurs inside the burrow in the damage stem.

Pachydiplosis oryzae, W.M. Mani

COMMON NAMES: Rice Gall Midge, Rice Gall Fly.

DISTRIBUTION AND IMPORTANCE: This pest occurs sporadically in most rice-growing tracts, and has been reported from Assam, Bihar, West Bengal, Madhya Pradesh, Orissa, Andhra, Pradesh Madras and Mysore States. In Orissa, it is reported to cause 100 per cent. damage in some areas, though at Cuttack only 15 per cent. damage has been recorded. A loss of 28 per cent. has been reported from the Hyderabad area of Andhra Pradesh.

Symptoms, Damage and Habits: Infested tillers show long, hollow tubular galls called 'silver shoots,' resulting in the death of the tillers. The adult is a small mosquito-like fly and is phototropic. After hatching, the grub enters the stem at the base. As a result of the irritation caused by the feeding grub, the tiller turns into a 'silver shoot.' The entire life-cycle is spent within a single tiller. Grubs pupate inside the galls and the pupae ascend the tubes before they emerge as adults. Depending on the weather conditions, the peak of infestation fluctuates between the end of August to the end of November. The number of broods varies from five to eight.

Leptocorisa acuta Thun., *L. varicornis* Fabr.

Common Names: Rice Bugs, Rice Ear Bugs, *Gundhi* Bugs, Stink Bugs.

Distribution and Importance: Two species of rice bugs occur in all the rice tracts, causing 10 to 40 per cent. loss to the crop. In recent years, they have assumed epidemic proportions, and in the year 1952, they infested seven million to eight million acres of rice in Uttar Pradesh, Bihar, Madhya Pradesh and Orissa (Pruthi, 1953). *L. varicornis* is a major pest in Assam, Bihar, Delhi, Madhya Pradesh, Madras, Orissa, Rajasthan, Kerala and Uttar Pradesh, but is a minor pest in Ajmer, Himachal Pradesh, Kashmir and the Punjab. *L. acuta* is a major pest in Madhya Pradesh, Madras, Orissa, Kerala and West Bengal, while it is a minor pest in Rajasthan, Bombay, Himachal Pradesh, Mysore and Uttar Pradesh.

Symptoms, Damage and Habits: Both nymphs and adults suck the juice from developing grains by means of their proboscis. Grains are attacked at the milk stage while mature grains are immune. Infestation by bugs is characterised by the presence of some empty or ill-formed grains in a panicle. Bugs are also known to suck the sap from the branches and rachii of ear and cause completely chaffy grains on some rachii. A hole is left on the grain where the bug punctures it around which a brownish spot develops. The bugs are phototropic. Nymphs on hatching suck the developing grains anf fall into the water when disturbed. Large swarms of bugs fly from one field to another, usually at nights. They emit a nauseous odour indicating the presence of the pest in a field even from a distance.

Hispa armigera Ol., *H. aenescens* Baly.

Common Name: Rice Hispa.

Distribution and Importance: Rice Hispa is a major pest in Andhra Pradesh Assam, Bihar, the Punjab, Madhya Pradesh, Manipur, Orissa, Kerala and West Bengal, but is a minor pest in Bombay, Himachal Pradesh, Kashmir, Madras, Mysore, and Uttar Pradesh. The loss caused by this pest is reported to be 39 to 65 per cent. in the Hyderabad area of Andhra Pradesh.

Symptoms, Damage and Habits: The grubs mine into leaf tissues and pupate inside the leaf. The adults feed on leaves, causing the characteristic white parallel lines. The infested crop becomes stunted and leaf-tips dry up. There are three to four generations in a year.

Leptispa pygmaea Baly.

Common Name: Rice Leptispa.

DISTRIBUTION AND IMPORTANCE: This is a major pest in Mysore and minor in Assam, Bombay, Madras, Orissa and Kerala. The grubs feed on the upper surface of leaves. The attacked leaves usually fold over, thus concealing the grubs.

Spodoptera mauritia Boisd.

COMMON NAMES: Armyworm, Swarming Caterpillar.

DISTRIBUTION AND IMPORTANCE: This is a sporadic pest. Ito ccurs as a major pest in the Andaman and Nicobar Islands, Andhra Pradesh, Assam, Bombay, Madhya Pradesh, Madras, Manipur, Orissa, Rajasthan, Kerala and West Bengal and as a minor pest in Bihar, Himachal Pradesh, Mysore and Uttar Pradesh. It is reported to cause a loss of 40 to 50 per cent. in Assam and 100 per cent. in some areas of West Bengal.

SYMPTOMS, DAMAGE AND HABITS: Caterpillars nibble at leaves, and in case of severe infestation, entire seed-beds are destroyed, orthe crop damaged to such an extent that the field appeass as if it has been grazed by cattle. The moths are active during nights, and are phototropic. During the day, they rest under the leaves and in relatively cool and shady spots. The larvae feed voraciously on the leaves, mainly during nights, and hide in the crevices of the soil during the day. They migrate from one field to another during nights. They dig into the soil and pupate. The number of generations varies from two to four in a year.

Cirphis unipuncta Haw.

COMMON NAMES: Armyworm, Climbing Cutworm.

DISTRIBUTION AND IMPORTANCE. This is a sporadic pest and is reported as major in Assam, Andhra Pradesh, Manipur and Orissa, and minor in Himachal Pradesh, Madhya Pradesh, Madras, Uttar Pradesh and West Bengal.

SYMPTOMS DAMAGE AND HABITS: Similar to those described for *Spodoptera*, but the larvae attack earheads also.

Hieroglyphus banian F., *H. nigrorepletus* Bo., *H. oryzivorus* U., *Oxya velox* F.

COMMON NAME: Rice Grasshopper.

DISTRIBUTION AND IMPORTANCE: The grasshoppers are major pests in Andhra Pradesh, Bombay, Madhya Pradesh, Madras, Orissa, the Punjab and Rajasthan and minor in Assam, Himachal Pradesh, Kashmir, Madhya Pradesh, Mysore, Uttar Pradesh and West Bengal. These cause, on an average, 20 per cent. loss. Severe infestations in Bombay and in one district of Madras caused over 50 and 90 per cent. losses respectively, and when they broke out in an epidemic form in Rajasthan, they completely destroyed the crop (Pruthi, 1950).

SYMPTOMS, DAMAGE AND HABITS: Both nymphs and adults feed on leaves, which appear partly eaten. In cases of severe infestation, plants may entirely be eaten up or reduced to mere mid-ribs and stalks. The adults are sturdy fliers.

Nephotettix bipunctatus Fab., *Nephotettix apicalis* Mots.

COMMON NAME: Rice Leafhopper.

DISTRIBUTION AND IMPORTANCE: These are distributed in all the rice-

growing regions, and are occasionally serious in Andhra Pradesh , Madhya Pradesh and Orissa under favourable conditions, and minor in Assam, Bihar, Madras, Mysore, Kerala, West Bengal and Uttar Pradesh. They are commonly known to cultivators and residents near rice fields as flies which hover about near lamps, particularly after a rain. They have been reported to have damaged three million acres of rice in one division in Madhya Pradesh in the year 1914 (Misra, 1920).

Symptoms, Damage and Habits: Both nymphs and adults suck juice from the sheaths and blades of leaves, due to which leaves appear yellowish-brown and dried up. Often, a black sooty mould and the cast skins of nymphs are seen above water level on leaf sheaths and stems. The adults are highly phototropic. When plants are shaken, the nymphs and adults drop into the water and climb up again.

Nilaparvata sordescens Linn.

Common Name: Rice Fulgorid.

Distribution and Importance: This pest is of common occurrence, and is often found in association with *Nephotettix* species. It is a serious pest in some years in Andhra Pradesh, Madras and Orissa, and is minor in Bihar, Madhya Pradesh, Mysore and Uttar Pradesh.

Symptoms, Damage and Habits: Similar to those described for *Nephotettix*.

Nymphula depunctalis Gn.

Common Name: Rice Caseworm.

Distribution and Importance: This pest is common in low-lying and deltaic rice fields, where water remains stagnant. This is a serious pest in the Andaman and Nicobar Islands, Andhra Pradesh, Assam, Bihar, Bombay, Madras, Manipur, Mysore and Orissa and is a minor pest in Madhya Pradesh, Kerala, Uttar Pradesh and West Bengal. Considerable damage is caused in cases of severe infestation.

Symptoms, Damage and Habits. In the nursery, leaves are eaten up by the larvae. Severe infestation in the field crop presents a frayed appearance. The larvae feed on the epidermis of leaves and lead a semi-aquatic life. They cut the leaves and roll them to form tubular cases which are often seen afloat on water or attached to stems at or above the water level. The larvae remain inside the cases and pupate. The moths are phototropic.

Cnaphalocrocis medinalis Gn.

Common Name: Rice Leaf Roller.

Distribution and Importance: This is a sporadic minor pest in West Bengal, Bihar, Bombay, Orissa, Madras, Andhra Pradesh, Mysore and Kerala.

Symptoms, Damage and Habits: The margins of leaf blades are folded and fastened with a few silk strands or the leaves are folded over themselves to form rolls. In case of severe infestations leaf margins and tips appear entirely dried up. The larva scrapes the green tissue of the leaves and remains inside the folded margins of leaf-blades where it pupates.

Thrips oryzae Will.

COMMON NAME: Rice Thrips.

DISTRIBUTION AND IMPORTANCE: This is a minor pest, and occasionally becomes serious causing considerable damage to seedlings. This is distributed in Andhra Pradesh, Assam, Madras, Mysore, Orissa and Kerala.

SYMPTOMS, DAMAGE AND HABITS: In the early stages of attack, the leaf surface shows yellow streaks. Later, leaves curl longitudinally from the margin to the middle and the tips wither. The seedlings present a scorched appearance. Nymphs and adults suck the juice from the leaves. The entire life is spent inside the leaf roll.

Ripersia oryzae Gr.

COMMON NAME: Rice Mealy Bug.

DISTRIBUTION AND IMPORTANCE: This is a pest common in the dry cultivated areas and in the uplands. It is a serious pest in Madras, and is a minor pest in Andhra Pradesh, Mysore, Orissa, Madhya Pradesh and West Bengal.

SYMPTOMS, DAMAGE AND HABITS: Infestation is localised in patches and the plants appear stunted and scorched. In cases of severe infestation, ears are not formed. The bugs are found in colonies between the stem and the leaf sheath. When a leaf sheath is drawn, numerous bugs, covered with a white mealy powder are seen.

Tetraneura hirsuta Butl.

COMMON NAME: Rice Root Aphid.

DISTRIBUTION AND IMPORTANCE: This is a minor pest reported from Madras, Orissa and Kerala.

SYMPTOMS, DAMAGE AND HABITS: Like the mealy bugs, these are found in colonies but below the soil surface on the roots and rootlets of the plants. The soil becomes loose around the infested plants, and ants are found in association with the aphids. Both nymphs and adults suck the sap from roots and root-hairs, causing curling and drying up of leaves.

Gecarcinucus jaccuemontii M.E., *Pratelphuse guerinf* M.E.; *P. jaccuemontii Rathb.*, *Puaratelphusa spinigera*; *P. hydrodromus* H., *P. sexpunctatum.*

COMMON NAME: Crabs.

DISTRIBUTION AND IMPORTANCE: Crabs are commonly found in rice fields. They cause great damage to rice in Bombay, where the first four species occur. The last two species occur as minor pests in Andhra Pradesh, Madras and Orissa.

SYMPTOMS AND DAMAGE: Crabs cause damage both in seed-beds and transplanted crop. They cut the plants near the ground level and carry them to their holes. They make a series of holes in the bunds, due to which the holding of water in the field becomes difficult.

Viviparus variatus F., *Pila virens* L., *Indoplanorbis exustus* D., *Limnae acuminata* L.

COMMON NAME: Snails.

DISTRIBUTION AND IMPORTANCE: All these are commonly found in all rice fields, but *Viviparus variatus* is predominant. They are serious pests in Andhra Pradesh and Kashmir. In the former State, they cause a loss of Rs. 40 to Rs. 80 per acre (Thirumala Rao *et al.* 1953).

SYMPTOMS, DAMAGE AND HABITS: Transplanted seedlings are cut 5 to 8 cm. below the water level during nights in an irregular serrated fashion. The cut stubbles rot away under submerged conditions. Usually, about 10 to 15 per cent. of the seedlings are destroyed, and the cultivators have to retransplant seedlings (Thirumala Rao *et al.*, 1953).

Gunomys kok G., *Millardia meltada* G., *Tatera cuvieri* W., *Bandicota bengalensis* G. & H., *Rattus rattus* BL., *Brevicaud alus.*

COMMON NAMES: Mole Rat, Grass Rat, Gervil Rat, Bandicoot, Rice-field Rat.

DISTRIBUTION AND IMPORTANCE: Common in all rice tracts.

SYMPTOMS, DAMAGE AND HABITS: In a young crop, seedlings are cut at the base. At the ear stage, grains are rendered chaffy by the nibbling at the stalks of the growing panicles, or the ear with grains are cut and dragged into the burrows to be used as food. The damage is caused only at nights. During the day, the rats remain inside the holes along the field bunds.

PESTS OF STORED PADDY AND RICE

After the harvest of paddy, it is usually stored for a long time either for consumption or for seed. During storage, grain is susceptible to damage by insects, rats and dampness, as a result of which it deteriorates both in quantity and quality. Even at the most conservative estimate, the annual loss caused by insect pests to the food grains stored is roughly 2.5 million tons (Narayanan, 1953). Further, under favourable conditions of temperature and moisture, infested grain stocks develop 'hot spots', resulting in secondary infection by fungi, bacterial etc., which serve as favourable media for the rapid multiplication of insects. About 50 species of insects are found damaging grain in storage, but only a dozen of them are common to both paddy and rice. Four of these insects enjoy world-wide distribution, and are major pests on stored rice. Owing to their minute size, these pests pass unnoticed till their population is built. up to enormous proportions. The following are some of the more important pests.

Sitophilus oryza L., *Sitophilus granarius* L.

COMMON NAMES: Rice Weevil or Black Weevil and Granary Weevil.

DISTRIBUTION AND IMPORTANCE: These two weevils are world-wide in distribution. The Rice Weevil is supposed to be a native of this country, while the Granary Weevil is considered exotic and is less prevalent. Both the adults and grubs are voracious feeders and render the grain unfit for consumption.

Tribolium castaneum Herb.

COMMON NAME: Red Rust Flour Beetle.

DISTRIBUTION AND IMPORTANCE: The Red Rust Flour Beetle is found all

over the country, causing considerable damage to stored paddy and rice as a secondary pest. This is found in company with other pests, completing the destruction started by other primary pests.

Rhizopertha dominica Fabr.

COMMON NAME: The Lesser Grain Borer.

DISTRIBUTION AND IMPORTANCE: This is also known as the Australian Wheat Weevil, and is a major pest of stored paddy throughout India. Both the larvae and adults feed on sound grains, reducing them to mere papery shells. The powder of the grain is webbed into a tangled mass of excreta.

Sitotroga cerealella Oliv.

COMMON NAMES: Angoumois Grain Moth, Rice Grain Moth.

DISTRIBUTION AND IMPORTANCE: This is distributed all over the world, and is one of the worst pests of paddy. The damage is caused entirely by larvae, which burrow inside the kernel of the grain and feed on the kernel.

CHAPTER 9

RICE RESEARCH CENTRES AND THEIR HISTORY

Research on rice in India may be said to have started in 1911 with the appointment of a special Botanist in the then Province of Bengal. Almost immediately afterwards, a special Botanist for rice was appointed in Madras. Since then rice research has gradually been taken up by all the rice-growing States, and at present 82 research stations, distributed all over the country (vide Table 10) are conducting the research on this crop. The location of these stations is shown in Fig. 31.

TABLE 10. RICE RESEARCH STATIONS IN INDIA

State	No. of stations	State	No. of stations
Andhra Pradesh	13	Madras	8
Assam	3	Mysore	7
Bihar	9	Orissa	3
Bombay	15	Punjab	2
Kashmir	2	Uttar Pradesh	4
Kerala	8	West Bengal	5
Madhya Pradesh	2	Union Government	1

Till 1930, however, Bengal and Madras were the only States which had wholetime Botanists for rice work. The other major rice-growing States either did not have such an officer, for the crop, or if there was a Botanist, he was engaged in dealing with several other crops, and work on rice was only a side-line for him. This state of affairs, however, changed, and rice research in the country received an impetus with the establishment of the Imperial (now Indian) council of Agricultural Research (I.C.A.R.) in 1929. In view of the significant role played by rice in the economy of the nation and recognising the need for stimulating research on the crop, the Council, since its inception, has been sponsoring and aiding rice-breeding projects in the various States as one of its major schemes. It was with the help of the Council that States like Bihar, Orissa, Madhya Pradesh and Uttar Pradesh were able to appoint special staff and institute rice-breeding work.

All the rice research stations in the country, except one *viz.* the Central Rice Research Institute, are maintained and operated by the various State Governments. The Central Rice Research Institute is a concern of the Central Government. While the State rice research stations are primarily breeding centres and mostly engaged in tackling breeding and agronomical problems, many of them undertake

investigations connected with the genetics, pests and diseases of the crop. A brief survey of the rice experiment stations in the country is given below.

Assam. Dr. S.K. Mitra, the Economic Botanist in charge of the rice work in the early years, was responsible for a number of improved strains evolved in Assam and also for valuable contributions to the genetics of rice.

At present, there are three rice research stations in the State, located at Karimganj in Silchar District, Titabar in Sibsagar District and Rohu in Nowgong District. All the three Stations are engaged in the breeding of high-yielding strains with desirable commercial qualities and improvement in agronomic practices. Twenty-nine improved strains have been released by Assam.

The Rice Experimental Station at Karimganj is the oldest, and was established in 1913. However, systematic breeding work at the Station was started only in 1921 with the appointment of the Economic Botanist. Prior to this, the work at this Station was supervised by the Economic Botanist of Bengal. The Station works on *ahu* or summer and autumn rices, *bao* or medium and deep water rices and *sali* or transplanted winter rices of the Surma valley.

The Rice Experimental Station at Titabar was established in 1923 for work on *ahu* and *sali* rices of the Brahmaputra valley.

The Rice Experimental Station at Rohu was started in 1948 for work on *bao* and *boro* or spring rices, and since 1954, the work on breeding of flood resistant rices has also been taken up at this Station. The Rohu Station has been opened to replace the Station at Habibganj, which was started in 1934 with the help of the Indian Council of Agricultural Research in Sylhet district for work on *bao* and *boro* rices of the low-lying areas, but on account of the partition of the country, it is now included in East Pakistan.

Andhra Pradesh. This State has 13 rice research stations located at Himayetsagar in Hyderabad district, Samalkot in East Godavari District, Maruteru and Pulla in West Godavari District, Anakapalle in Visakhapatnam District, Masulipatam on the sea coast in Krishna District, Buchireddipalem in Nellore District, Amberpet in Hyderabad District, Rudroor in Nizamabad District, Dindi in Nalgonda District, Ragole in Srikiakulam District, Kamalapuram in Cuddappah District and Yemiganur in Kurnool District.

The Main Government Agricultural Experiment Station at Himayetsagar established in 1928 is the chief centre of rice research in the State. With the strengthening of the staff and improvement of facilities in 1950, work was greatly expanded, and now includes breeding, agronomic investigations, soil studies, rice pathology and entomology. As a result of the breeding work done, 14 improved strains from the local varieties have been released from this station. At present, breeding work is mostly concentrated on evolving high-yielding varieties which have good fertilizer response and are non-lodging and non-shedding.

The Agricultural Research Station at Samalkot is the oldest in the State. The Station was opened in 1902 mainly for the study of sugarcane. Work on rice at the Station was started in 1909 and 19 improved strains from the more important local varieties have been evolved.

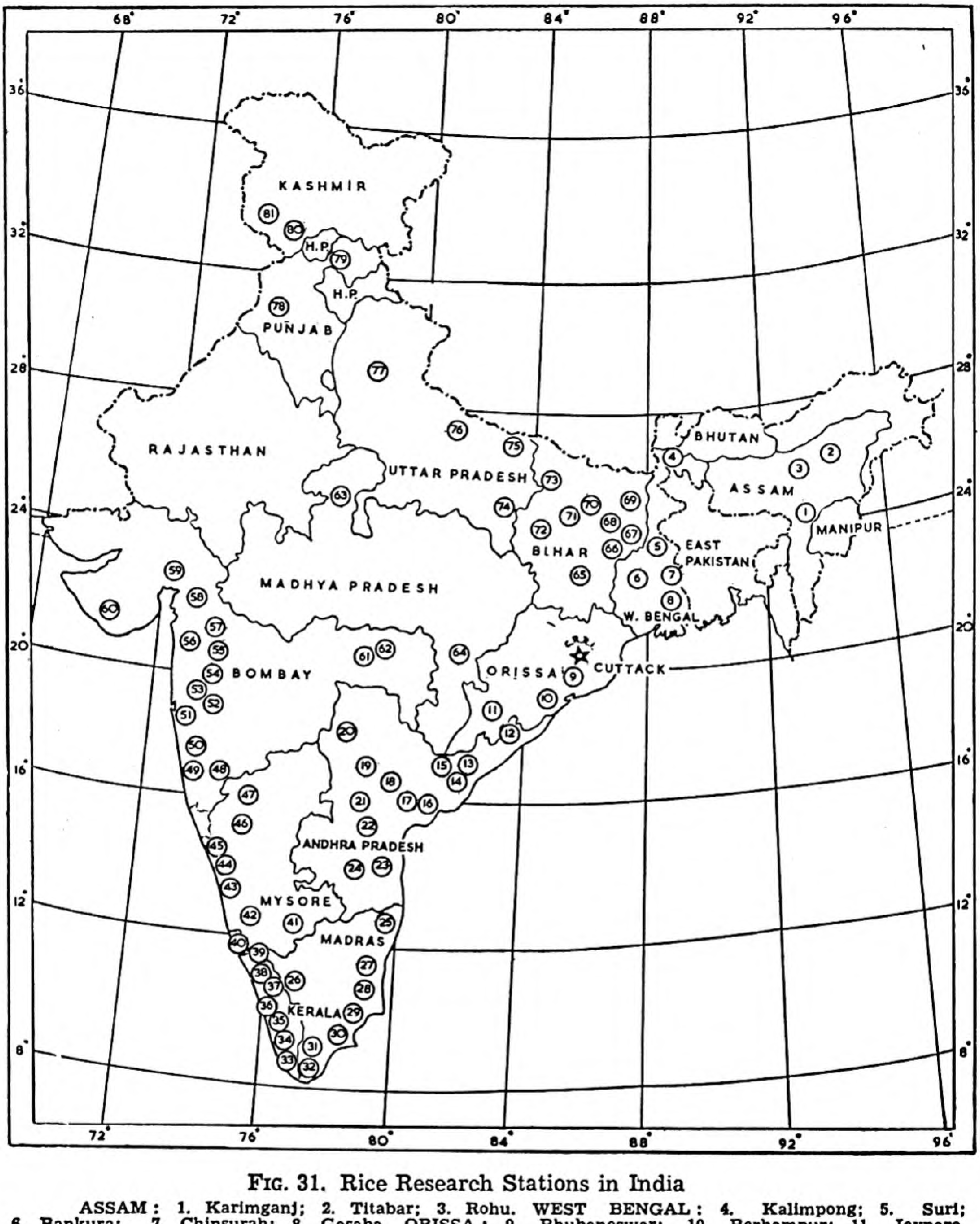


FIG. 31. Rice Research Stations in India

ASSAM: 1. Karimganj; 2. Titabar; 3. Rohu. WEST BENGAL: 4. Kalimpong; 5. Suri; 6. Bankura; 7. Chinsurah; 8. Gosaba. ORISSA: 9. Bhubaneswar; 10. Berhampur; 11. Jeypore. ANDHRA: 12. Anakapalli; 13. Samalkota; 14. Masulipatam; 15. Pulla; 16. Maruteru; 17. Buchireddipalem. MADRAS: 18. Coimbatore; 19. Tirurkuppam; 20. Palur; 21. Aduthurai; 22. Pattukottai; 23. Paramakuki; 24. Ambasamudram; 25. Pattambi; 26. Taliparamba; 27. Ambalavayal; 28. Mangalore. TRAVANCORE-COCHIN: 29. Oilukara; 30. Alwaye; 31. Monkompu; 32. Kayamkulam; 33. Kottarakara; 34. Nagercoil. COORG: 35. Ponnampet. MYSORE: 36. Nagenhalli. HYDERABAD: 37. Himayatsagar; 38. Rudroor; 39. Dandi; 40. Dhanesagur. BOMBAY: 41. (a) Kumta (b) Kumta salt land; 42. Sirsi; 43. Mugad; 44. Radhanagari; 45. Phondaghat; 46. Ratnagiri; 47. Vadgaon; 48. Karjat; 49. Panvel; 50. Igatpuri; 51. Kosbad; 52. Waghai; 53. Dabhoi; 54. Nawagam. MADHYA PRADESH: 55. Raipur. BIHAR: 56. Ranchi; 57. Dumka; 58. Sabour; 59. Monghyr; 60. Purnia; 61. Pusa; 62. Patna; 63. Bikramganj; 64. Sepaya. UTTAR PRADESH: 65. Tissuli; 66. Gorakhpur; 67. Pachperwa; 68. Nagina. VINDHYA PRADESH: 69. Revara Farm. MADHYA BHARAT: 70. Bhilsa. PUNJAB: 71. Gurdaspur; 72 Nagrota Bagwan. KASHMIR: 73 .Khudwani; 74. Shalimar.

• CENTRAL RICE RESEARCH INSTITUTE, CUTTACK (Orissa)

The Agricultural Research Station at Anakapalle was started in 1913 mainly for work on sugarcane. The work on rice was taken up at the Station in 1923 for breeding high-yielding, disease and drought-resistant strains. Twelve improved strains from the local varieties to suit different conditions in the tract have been released.

The Agricultural Research Station at Maruteru was opened in 1925 to cater to the needs of the west and central portions of the Godavari delta. Strains suitable for the first crop, second crop, rain-fed areas and submersible lands have been evolved. In all, 22 improved strains have been released from this Station.

The Rice Research Station at Buchireddipalem was started in 1937 for breeding high-yielding, blast-resistant strains from the variety *Molakolukulu* or *Nellore samba*. This is the predominant variety of the area and has a high reputation for quality, but is subject to Blast disease. So far, five strains, high-yielding and fairly resistant to Blast, have been evolved and released from the Station.

The Deep Water Paddy Station at Pulla was started in 1950 for breeding varieties able to withstand floods of varying depths and short periods of immersion. Work done so far has highlighted some selections and introductions which are promising.

The Saline-resistant Rice Research Station at Masulipatam was opened in 1954 for breeding saline-resistant strains. Work at this station as well as at Pulla is being aided by the Indian Council of Agricultural Research.

The Agricultural Research Station at Rudroor located in the heart of the perennially irrigated Nizamsagar Project area, was established in 1930 but intensive work on rice was started only in 1942. Three improved strains from the local varieties have been released from the Station. Besides breeding, investigations relating to cultural practices, green manuring and pest incidence are in progress. The Dindi Station in Nalgonda district was started in 1946 to tackle the problems of rice cultivation in the area irrigated by the Dindi Project.

The Station at Amberpet was acquired in 1951. Seed multiplication and trial of Blast-resistant varieties is being done at this station.

The stations at Yemmiganur and Ragole are research-cum-demonstration centres and were started in 1955 and 1956 respectively, while the research Station at Kamalapuram was started only in November, 1957.

Bihar. The work on rice started in Bihar as far back as 1914-15. The early work on rice in the State was controlled by the Deputy Directors, and was mostly devoted to varietal trials and agronomical investigations. Nevertheless, selection work in the local varieties was also undertaken, and resulted in the production of some improved strains.

Rice research in the State received considerable impetus with the starting of a breeding project by the Indian Council of Agricultural Research in 1932, which continued till 1949. Special staff was recruited for the work with the late Mr. Alam as the first Rice Research Officer. His work has led to most of the breeding and genetical investigations reported from the State. The work was carried out mostly at Sabour, which is the main rice research centre of the State. With the termination of the scheme sponsored by the Council in 1944, rice research in the State received

a set-back. The work has, however, recently been reorganised, the staff has been strengthened, and eight botanical sub-stations opened at Ranchi, Patna, Bikramganj, Sepaya, Pusa, Purnea, Dumka and Monghyr.

Bombay. Rice research has received considerable attention in Bombay State. Besides the breeding of improved strains, which has resulted in the release of 45 high-yielding strains, the work has covered the fields of genetics, agronomy, plant physiology, biochemistry, pests and diseases. The early work on rice in the State consisted of investigations on agronomic practices. The post of a Plant Breeder was created in 1917 for the improvement of rice, wheat and cotton, and rice breeding was started in 1919 with single plant selection work in the variety *Kolamba* by Mr. H. M. Chibber. In 1930, Dr. B. S. Kadam was appointed Crop Botanist. He has been largely responsible for the breeding work done in the State, and has considerably added to the knowledge of the genetics of the crop.

There are 15 Agricultural Research Stations working on rice in Bombay State, located at Karjat, Panvel and Khopoli in Kolaba District, Vadgaon in Poona District, Palghar in Thana District, Dahboi in Baroda District, Nawagaon in Kaira District, Ratnagiri and Phondaghat in Ratnagiri District, Radhanagiri in Kolhapur District, Igatpuri in Nasik District, Waghai in Dangs District, Nagpur and Sindewahi in Nagpur District and Junagadh in Sorath District.

Rice-breeding work started in Bombay at Karjat in 1919 and the Station at Ratnagiri was opened soon afterwards . In 1940, the Vadagaon and Igatpuri Stations were started, mainly for work on the scented and fine-grained rice varieties of the Deccan. In 1945, two stations were started in Gujarat, one at Bulsar which was shifted in 1953 to Kosbad and is now located at Palghar in Thana District and the other at Nawagaon, under a scheme partly financed by the Indian Council of Agricultural Research. A comprehensive rice research scheme was initiated in 1947, and the stations at Panvel, Dhavoi, Phondaghat, Radhanagiri and Waghai were started for work on the unexploited varieties of the different regions.

The Karjat and Palghar Stations serve north Konkan, where a fine grained variety *Kolamba*, is extensively grown. The Agricultural Research Station at Karjat in Kolaba District is the chief centre of rice research in the State. Some nine improved strains have been released from this Station. Work is also in progress to evolve Blast-resistant strains, high-yielding strains responsive to heavy fertilization, and strains resistant to lodging, grain-shedding and Bacterial Blight. The Agricultural Research Station at Palghar in Thana District has been started only recently.

The Agricultural Research Stations at Ratnagiri and Phondaghat serve South Konkan. At Ratnagiri, selection in important local rice varieties was started in 1923, and five improved strains have been released. One of these, *viz.*, *Patni*-6, is reported to be resistant to the storage moth also. Phondaghat is a new station, and work on the improvement of local varieties in the northern parts of Ratnagiri district is in progress.

The station at Panvel (Kolaba district) was opened in 1949 for improvement of the major salt land rices of the North Konkan coastal area. Two improved strains have been released. A hybridization project to combine quality with saline resistance is being carried out, and some promising selections have been made.

The Agricultural Research Stations at Nawagaon (Kaira District) and Dabhoi (Baroda District) serve the Gujarat tract. The Nawagaon Station was established in 1945 for work on rice of North Gujarat. Four selections from local varieties have been released. At the Dabhoi Station, work on drilled rices is in progress.

The Stations at Vadgaon, Igatpuri and Radhanagiri serve the Maval tract. Scented rice varieties are predominantly grown in this tract. At the Vadgaon Station in Poona district, work on rice was started in 1940, and three improved strains of scented rice and one of non-scented rice have been released. Work at the Igatpuri Station in Nasik District was started in 1941, and two improved strains have been released. At the Radhanagiri Station, work has recently been started on the improvement of rice of Kolhapur District.

At the Waghai Station, work has been in progress since 1953 for the improvement of varieties in Dangs district.

The station at Khopoli in Kolaba District is an experiment-cum-demonstration centre. This was started in 1950 for undertaking breeding and agronomic research on *waingan* or hot weather rices and agronomic experiments on vegetables.

Madras. Work on rice has from the very beginning formed an important activity of the Agricultural Department. Though no intensive botanical work was attempted in the earlier years, the improvement of cultural and manurial practices received considerable attention. Intensive research on the crop started with the appointment of an Economic Botanist in 1912 (later designated Paddy Specialist). Mr. F.R. Parnell, the first Paddy Specialist in Madras, was succeeded by Dr. K. Ramiah in 1924. Dr. Ramiah had been associated with Mr. Parnell from almost the very beginning, and the breeding work done in Madras is very largely due to the efforts of this pre-eminent worker in the field of rice research. Dr. Ramiah's great contributions to genetics and other fields of research on the crop have considerably widened the knowledge of the rice plant.

There are at present eight rice research stations in Madras State, located at Coimbatore, Aduthurai, Pattukkottai, Ambasamudram, Tirurkuppam, Paramakudi, Palur and Nagercoil. These stations are engaged in the isolation of high-yielding strains from local varieties and breeding strains resistant to lodging, blast, drought, floods, alkalinity, salinity and loss of viability in storage in areas with heavy rainfall. Work is also in progress to breed strains responsive to heavy fertilization and to introduce dormancy in short duration strains. Besides breeding, investigations on the manurial and cultural practices and artificially induced mutations are in progress. So far, 110 improved strains have been released.

The central region and the east coast of the State are served by the stations at Coimbatore, Palur and Tirurkuppam. The Paddy Breeding Station at Coimbatore was started in 1913, and is the chief centre of rice research in the State. Twenty-three improved strains from local varieties and five hybrid strains have been released. Considerable genetical and agronomic work has been carried out at this Station.

The Agricultural Research Station at Palur in South Arcot District was started in 1905, and three improved strains have been released. The Rice Research

Station at Tirurkuppam in Chingleput district was started in 1942 to tackle the problems arising in areas of precarious and inadequate water supply and undependable rains of the central districts. Five improved strains from the local varieties and one hybrid strain have been released.

The stations at Aduthurai and Pattukkottai, both in Tanjore District, serve the Cauvery deltaic area. The Agricultural Research Station at Aduthurai was opened in 1922, the first substation to be started in pursuance of the policy to provide facilities for the improvement of the crop in each of the most important rice tracts. Twenty-two improved strains from the local varieties and three hybrid strains have been released from this Station. Work on the breeding of short and medium duration strains resistant to Blast, resistant to flood, salinity, and short duration strains with seed dormancy is in progress.

The Agricultural Research Station at Pattukkottai was started in 1935 to cater to the needs of the area under the Cauvery Mettur Project in Tanjore District. Work on the improvement of the local varieties is in progress.

The stations at Ambasamudram and Paramakudi serve the southern region of the State.

The Rice Research Station at Ambasamudram in Tirunelveli District was started in 1937 for work on rices of the Tambraparani valley. Ten improved strains from the local varieties and one hybrid strain have been released.

The Agricultural Research Station at Paramakudi in Ramanathapuram District was started in 1953, and work on the breeding of superior strains from the local varieties and of drought-resistant strains is in progress.

The station at Nagercoil was started in about 1914 for work on the rice problems in the Nanjinad region of the former Travancore-Cochin State. With the reorganization of States in 1956, this Station has come under Madras State, and is engaged in the multiplication of improved rice strains.

Madhya Pradesh. There are two rice research stations in the State, located at Raipur and Bagwai. The Station at Bagwai was opened in 1908. In the early years, most of the experimental work at this Station was confined to agronomical investigations. The Economic Botanist, Dr. Graham, with his headquarters at Nagpur, could only devote part of his time to rice. However, some progress was made in evolving improved strains of rice. With the retirement of Dr. Graham in 1915, the work on rice received a set-back, but with the appointment of a Second Economic Botanist in 1924, fresh stimulus was given to the work on rice.

Rice breeding work at the Raipur Station was reorganised in 1932 as part of the co-ordinated scheme of rice investigations of the I.C.A.R. A full time Rice Research Officer, Mr. B.B. Dave, was appointed, who has been responsible for breeding some valuable strains at this station. Eighteen improved strains have been released. These include ten medium and coarse-grained strains., four fine-grained scented strains and four purple-pigmented strains for cultivation in areas infested with wild rice. The development of rice research in Madhya Pradesh again received a set-back when the assistance given by the I.C.A.R. terminated. However, work on the crop has recently been renewed at Raipur under a new project sponsored by the I.C.A.R. Under this project, work on the breeding of

high-yielding strains of different durations, blast -resistant strains, non-lodging, non-shedding strains, and agronomic investigations are in progress.

At the Bagwai Research Station, breeding of high-yielding, medium and fine quality rices of different durations suitable for the irrigated area in North Madhya Prades tract of the State is in progress, since 1953 with the financial aid made available by the I.C.A.R.

Mysore. In this State, there are seven Research Stations working on rice, located at Nagenhalli, Poonampet, Kumta, Sirsi, Kumta (salt land), Mugad and Mangalore. The Agricultural Research Station at Nagenhalli is situated in the area served by the Cauvery channels and was started in 1917 as a demonstration and experimental farm for sugarcane and rice. In the beginning, work on rice consisted of cultural, varietal and breeding trials. As the rice acreage in the channel-fed area increased, the farm was converted in 1938 into a rice breeding station, and work on the improvement of the crop was started. So far, 21 improved strains of local varieties and three hybrid strains have been released. Besides breeding, investigations on manurial and cultural practices and on the control of diseases are in progress.

The Agricultural Research Station at Poonnampet was started in 1951 for breeding and agronomic investigations in Coorg under a scheme financed by the Indian Council of Agricultural Research.

The Agricultural Research Stations, Mugad, Kumta, Sirsi and Kumta (salt land) were originally under Bombay State, and were included in Mysore on the reorganisation of States in 1956.

The Mugad Station in Dharwar District ws established in 1922, and serves the Malnad tract. This tract grows a very coarse, white-karnelled rice, which is cultivated as a drilled crop. Ten improved strains have been released from this Station ; some of the Mugad strains are reported to be highly resistant to blast. Since the fields in Malnad tract are infested with wild rice, the strains with a purple sheath released by the Station are useful in combating the wild rice menace in the area.

The Station at Kumta in North Kanara District was started in 1948. Four improved strains have been released from this Station and another selection, which is very promising, is under large-scale trials. Work is also in progress to evolve strains combining quality and resistance to blast disease. The Kumta (salt land) Station was opened for improvement of salt land varieties of the South Konkan coastal area. The Sirsi Station, also in North Kanara District, was opened for improvement of the rice crop of the Upghat areas, and selection in the principal local varieties is in progress. Special attention is being paid to breeding of Blast resistant varieties. The Paddy Breeding Station at Mangalore, formerly under Madras State, was opened in 1942 for the improvement of rice in South Kanara District. Two improved strains have been released.

Orissa. The chief rice research centre of the State in the early days was located at Cuttack. This Station was started in 1932, when Orissa and Bihar were a single administrative unit, as a sub-station of the main rice research station of the province at Sabour (Bihar). With the formation of Orissa as a separte province

in 1936, Cuttack became the main rice research station of the new province. The I.C.A.R. sponsored a rice research scheme in Orissa from 1937 to 1944 with Mr. P.D. Dixit as the Paddy Specialist. Much of the credit for the varieties evolved and the agronomic work reported from Orissa goes to Mr. Dixit and his colleagues. The Cuttack Station was taken over by the Union Government in 1946 for the establishment of the Central Rice Research Institute. At present, there are three research stations in Orissa, located at Berhampore, Jeypore and Bhubaneswar, working on rice.

The Rice Research Sub-station at Berhampore, in Ganjam District, was originally started by the Madras Government with the financial assistance of the I.C.A.R., as a temporary station for five years in 1932, and by 1937, ten improved strains in the most important local varieties had been evolved. The Station was taken over from Madras by Orissa in 1937. The Rice Research Sub-station at Jeypore, in Koraput District, was opened in 1937 to serve what was then known as the Agency Area. The establishment of this Sub-station was facilitated by the generosity of the late Maharaja of Jeypore.

The State Agricultural Research Station at Bhubaneswar, the new capital of Orissa, was established in 1949 and work on rice has only recently been started there.

So far, 34 improved strains have been released, eight of them from Berhampore, nine from Jeypore and the remaining from the former Cuttack Station.

The Punjab. There are two rice research stations in the Punjab, located at Nagrota Bagwan in the hills, and Gurdaspur in the plains.

The Rice Breeding Station at Gurdaspur was established in 1950 for the improvement of rice of the Punjab plains. Prior to the partition of the country in 1947, this work was done at the station at Kala Shah Kaku, now included in West Pakistan. The work at Gurdaspur is financed jointly by the Punjab Government and the I.C.A.R. on a 50:50 basis. The Rice Breeding Substation at Nagrota Bagwan in Kangra District was started in 1936 to serve the hilly and submontane rice zone of the State. Eight improved strains from the local varieties have been released in the Punjab.

Kerala. There are eight Rice Research Stations in the State, located at Ollukkara, Monkompu, Kottarakkara, Alwaye, Kayamkulum, Pattambi, Ambalavayal and Taliparamba. Work on breeding for high yield resistance to flood and salinity and agronomic investigations are in progress.

The Central Farm at Ollukkura near Trichur was started in 1917. Work on the improvement of local varieties is in progress and an improved strain has been evolved.

The Paddy Breeding Station at Monkompu was established in 1940, under a scheme partly financed by the Indian Council of Agricultural Research till 1949, for work on rice of the *punja* areas of Central Travancore. Two improved strains have been released from this Station. Recently, work on breeding of saline and flood-resistant strains has been started.

The Paddy Breeding Station at Kottarakara is meant for breeding strains suitable for the lateritic areas in Central Travancore. This work was started at

Adoor in 1940 under a scheme partly financed by the Indian Council of Agricultural Research till 1949, and was shifted to Kottarakara in 1954. Ten improved strains, six for the *virippu* season and four for the *mudakan* season, have been released.

The Paddy Farm at Alwaye, situated in North Travancore was originally a sugarcane farm, and was converted into a rice station in 1951.

The Agricultural Research Stations at Pattambi, Ambalavayal and Taliparamba were formerly under Madras State and on the reorganisation of the State in 1956 were included in Kerala.

The Agricultural Research Station at Pattambi in Malabar District was opened in 1927. So far, 33 improved strains from the local varieties have been released from this station. Work on breeding of strains resistant to drought and flood, and early-maturing strains with seed dormancy, is in progress as also agronomic investigations.

The Agricultural Research Station at Ambalavayal (Wynad) in Malabar (hill tract) was opened in 1945. Two improved strains have been released, and promising cultures from other local varieties are under study.

The Agricultural Research Station at Taliparamba in Norh Malabar is an old Agricultural Research Station, started in 1915, with the object of investigating the *pollu* disease of pepper and to carry out trials with all the main crops of Malabar. Selection in the local rice varieties is now in progress.

Uttar Pradesh. Rice research began in this State in 1924, when a beginning in the collection of samples of rice varieties grown in the State was made. About 1,300 samples were collected and grown at Kanpur, the headquarters of the Economic Botanist. Kanpur, however, was not suitable for growing rice and in 1932, the rice work, under a scheme sponsored by the I.C.A.R., was shifted to Nagina and placed under a separate Economic Botanist. Mr. R.L. Sethi, who was appointed Economic Botanist for rice, did pioneering work on the crop, and contributed largely to the breeding, genetical and agronomical work on the crop reported from the State. Twenty-two improved strains from the local varieties and two hybrid strains have been released.

At present, there are four rice research stations in the State located at Nagina. Gorakhpur, Pachperwa and Tissuhi. The Rice Research Station at Nagina in Bijnor District is the main centre of rice research in the State. It was started in 1932 under a scheme financed by the I.C.A.R. From 1939, the Station was jointly financed by the I.C.A.R. and the State, and in 1944, the State assumed full responsibility for the Station. Most of the improved varieties released in Uttar Pradesh were evolved by Sethi and his co-workers at this Station.

The Rice Research Sub-station at Gorakhpur took up work on the rice cultivation problems in the unirrigated areas of eastern Uttar Pradesh. The Late Paddy Research Sub-station at Pachperwa in Gonda District was started in 1950 for the improvement of the long duration rices in the north-eastern area of the State. The Late Paddy Research Sub-station at Tissuhi in Mirzapur District, established in 1954, took up work on the long duration rices of the south-eastern parts of the State. At both these Stations, varietal, manurial and cultural investigations are in progress.

West Bengal. Before the partition of the country in 1947, Dacca, now in East Pakistan, was the chief rice research centre for the old province of Bengal. It was here that systematic rice research was first started in India 45 years ago, with the appointment of Dr. Hector as Economic Botanist. In West Bengal, there are five rice research stations at present, located at Chinsurah, Bankura, Suri, Gosaba and Kalimpong.

The Rice Research Station at Chinsurah, which serves the alluvial tracts of the State, was started in 1932, under a scheme financed by the I.C.A.R., and is now the chief rice research centre of the State. The Rice Research Station at Bankura, which serves the laterite region of the State, was also started in 1932 with the financial assistance of the I.C.A.R., and a sub station at Suri was also opened in 1932. These stations were started with the object of breeding improved strains from the local varieties to improve the quality of *patnai*, the quality table rice of Bengal with a foreign market, and the trade varieties other than *patnai*.

The Paddy Research Station at Gosaba has recently been started for the breeding of saline-resistant strains under a scheme financed by the I.C.A.R. The Rice Research Station at Kalimpong was started in 1949 for work on the improvement of hill rices under another scheme financed by the Council.

In West Bengal, 44 improved rice strains (nine *aus* and thirty-five *aman*) have been evolved. Besides these strains, there are a few strains introduced from other States, which are doing well.

Central Rice Research Institute, Cuttack. In 1944, the Government of India contemplated the setting up of an Indian Central Rice Committee for dealing with all problems of rice, namely, research, development, extension and marketing. It was proposed to provide finances for the Committee by levying a cess of six annas a ton on all rice hulled in any Power Mill in the then British India, but as public opinion in the country was not in favour of levying a cess on a food crop, the idea of instituting a Commodity Committee for rice was abandoned. The Government of India then decided to set up from its own funds a Central Institution for rice research in the country, and appointed Dr. K. Ramiah, who has devoted a life-time to rice research, as Special Officer to investigate and plan the project. On the recommendation of Dr. Ramiah, Cuttack was selected for the location of the Central Rice Research Institute and the Cuttack Station of the Orissa Government was taken over by the Union Government in 1946 to form the nucleus of the Central Government project. Dr. Ramiah, who was appointed as the first Director, brought his great experience of rice research in founding and organising the Institute.

The Institute was started to undertake fundamental research in all aspects of rice, to investigate into such problems as have a wide application, and act as a centre for authoritative information on the crop. It was originally planned that the Institute, in addition to work at Cuttack, have two substations, one for the study of salt water rices and the other for the study of rices growing under flooded conditions, which are problems facing a number of States. These proposals, however, had to be postponed for the time being, but it is now planned to start these stations during the Second Five-Year Plan period.

The Institute is organized to undertake investigations on agronomy, breeding, genetics, cytology, plant pathology, entomology, agricultural chemistry and soils and statistics. Work on plant physiology and agricultural engineering is shortly being started. The Institute also undertakes post-graduate training, and has in co-operation with the Food and Agricultural Organisation of the United Nations (FAO) twice held an International Training Course on Rice Breeding. The Institute is one of the world centres recognised by the FAO for the maintenance of genetic stocks registered by the rice-growing countries of the world with the FAO, and the Director of the Institute is charged with the overall supervision of this FAO project. The Institute also supervises the Extension work in the Intensive Cultivation Centre, covering some 8,000 acres, in its neighbourhood.

CHAPTER 10

BREEDING

The main problem in rice breeding in India is the production of high-yielding varieties, their multiplication and distribution for cultivation over large areas as quickly as possible, so as to increase the level of production per unit area. Results presented in this chapter pertain to the work done in different States as they were before their reorganization in 1956.

BREEDING FOR HIGH YIELD

Ever since systematic rice breeding was initiated in the country, the problem of improving the yield has received constant attention and has been the major objective in all the breeding projects undertaken. As there is enormous variation in the rice-growing conditions in India, varietal diversity is very great, and thousands of varieties, each suited to particular conditions of soil, season, rainfall, etc., are grown in different parts of the country. This has led to the low adaptability of rice varieties and therefore, cosmopolitan varieties which can thrive under a wide range of conditions are rare. Hence, breeding has to be localised, and a large number of improved strains have to be evolved.

The results of breeding for high yield have been spectacular in the country, and about 445 superior strains, giving on an average 10 to 20 per cent. better yield than the cultivators' varieties have been evolved in different rice-growing States, as shown in Table 11.

TABLE 11. NUMBER OF IMPROVED STRAINS EVOLVED BY DIFFERENT STATES IN INDIA

(POSITION UP TO THE REORGANIZATION OF STATES IN 1956)

State	Improved strains evolved by		Total	Yield of paddy in lb. per acre
	Selection	Hybridization		
Assam	23	6	29	1,640 to 3,690
Andhra Pradesh	52	7	59	1,500 to 4,300
Bihar	12	2	14	1,830 to 2,050
Bombay	44	1	45	1,250 to 3,140
Hyderabad	17	..	17	2,000 to 3,000
Madhya Pradesh	9	9	18	1,240 to 2,552
Madras	103	10	113	1,800 to 5,000
Mysore	17	8	25	.. ..
Orissa	31	3	34	1,000 to 4,000
Punjab	8	..	8	2,000 to 2,700
Travancore-Cochin (Kerala)	14	..	14	2,000 to 2,800
Uttar Pradesh	22	2	24	2,000 to 3,000
West Bengal	42	3	45	2,000 to 3,690
Total	394	51	445	

Most of the improved strains have been evolved by selection in natural populations. For this purpose, the most widely cultivated varieties in large concentrated tracts have been tackled, but there are still other rice tracts where natural variability has remained practically untouched, and breeding work on the improvement of varieties in such areas is in progress. Alongside with the exploitation of the natural population for the production of rice strains, hybridization projects are being vigorously carried out for the improvement of the rice crop in the various States. A list of improved varieties is given in Appendix IV.

Assam. Twenty-nine improved strains have been released from Assam. These strains which include nine *ahu*, five *bao*, eleven *sali* and four *boro* varieties, are very popular and are grown extensively in the State.

Andhra Pradesh. Fifty-nine improved strains have been released from Andhra Pradesh. These strains are popular and suitable for the various regions as shown below.

(*a*) Strains suitable for the Godavari delta

i. First crop season (June to December)

Mtu. 1, 2, 3, 4, 5, 6, 10, 11, 14 and *21*

SLO. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 17 and *18*

ii. Second crop season (January to May)

Mtu. 9, 15 and *20*; *SLO. 12, 16* and *19*; *Pla-1*

(*b*) Strains suitable for the Krishna delta

Mtu. 7, 8, 12, 13, 19 and *22*

(*c*) Strains suitable for submersible lands

Mtu. 16

(*d*) Strains suitable for rain-fed areas

Mtu. 17 and *Mtu. 18*

(*e*) Strains suitable for tank-fed areas and minor irrigation projects

Akp. 1 to *12*

(*f*) Strains suitable for late planting in Nellore, Chitoor and Cuddapah districts

BCP. 1 to *5*

It may be mentioned that *Mtu. 1* is a cosmopolitan strain suited to varied conditions, and can be grown even in the saline and occasionally submersible areas along the coast.

It was found that some of these released strains had certain defects like lodging, susceptibility to Blast and False Smut and chaffiness. A hybridization project was undertaken to rectify these defects, and as a result, some cultures with desirable characters have been obtained.

Bihar. In this State, 14 improved strains have been released. Of these, five are *aus* varieties, five are *aman* varieties, two are floating rices, and two are purple-pigmented varieties suitable for cultivation in fields infested with wild rice. Besides these, there are other eight *aus* (Chinese introdctions) and six *aman* strains which are reported to be very promising. Two flood-resistant strains of Orissa, *viz.*, *FR. 13 A* and *FR. 43 B*, renamed as *BR. 13* and *BR. 13 A* respectively, are reported to have been successfully introduced into the State.

Bombay. In this State, 45 improved strains suitable for the different tracts as shown below have been released.

1. North Konkan
   Kolamba 42, 184 and *540*
   Zinya-31, 149; *Kada 68-1*; *Bhadas 1303*; *Garvel 1-8*; *Mahadi 4-4.*
2. South Konkan
   Patni-6; *Panvel-61*; *Waksal-207*; *Warangal 487* and *Bhadas*-79.
3. Southernmost taluks of South Konkan and below the Ghats in N. Kanara
   Maskaty-1315, Halga-1690, Jaddu-1061
   Halga-244 and *Sanna Maliga-79*
4. Malnad tract
   Mugad-81, 141, 161, 249
   Antarsal-67, 90 and *200*
   D. 622, Waner-1 and *Yelikrisal 4*
5. Maval tract
   Ambemohar-157 and *159*; *Early Ambemohar-102*; *Chimansal-39*; *Krishnasal-1*; *Early Kolpi-70 and Late Kolpi-248*
6. Gujarat tract
   Kada 176-12; *Early Kolam 161-62*; *Sukhvel-20*; *Kanod-118*; *Pankhali-203*; *Early Sutarsal*
7. Coastal saline areas of Konkan
   Kala Rata-1-24 and *Bhura Rata-4-10*

Among the strains evolved, *Kolamba* and *Zinya* strains, *viz.*, *Kolamba-184* and *Kolamba-540*, *Zinya-31* and *Zinya-149*, *Early Kolpi-70*, *Early Kolam-161-62*, and some others are fine white rices; *Ambemohar-157* and *159*, *Krishnasal-1* and *Pankhali-203* are selections from scented rices. *Ambemohar*-157 is very popular in Poona District on account of its fine grain, scent and non-lodging habit. *Waner-1* and *Dadgya-622* are reported to be drought-resistant, while *Kala Rata-1-24* and *Bhura Rata-4-10* are suitable for saline areas.

Early Ambemohar-102 is a long, fine, slightly scented strain, which has been recently evolved. *Patni-6* is reported to be resistant to the Storage Moth; *Antarsals* strains *67, 90* and *200* are highly resistant to Blast, while *Mugad-81, 141* and *161* and *Waner-1* are Blast-tolerant. The *Mugad* and *Antarsal* strains with green and coloured leaf-sheath respectively, are cultivated in alternate years to combat the menace of *gonag* (wild rice) in the drilled areas of the Malnad tract.

Among the introduced types, *Basmati-370* from the Punjab is reported to be doing well under irrigation in the Deccan Canal area.

Hyderabad. In Hyderabad, the greater part of which is now merged with Andhra Pradesh, 17 strains have been released, 13 of which have been evolved by selection from the local varieties, and four by selection from introductions. These are given below.

1. Selections from local varieties
   *Hr. 1, Hr.*5, *Hr. 8, Hr. 12, Hr.21, Hr.33, Hr.*35, *Hr.38, Hr.39, Hr.59, Hr.67*; *Rdr.2,* and *Rdr.7*

Fig. 32. Emasculation of the rice flower (Forceps Method)

Fig. 33. Emasculation of the rice flower (Hot Water Method)

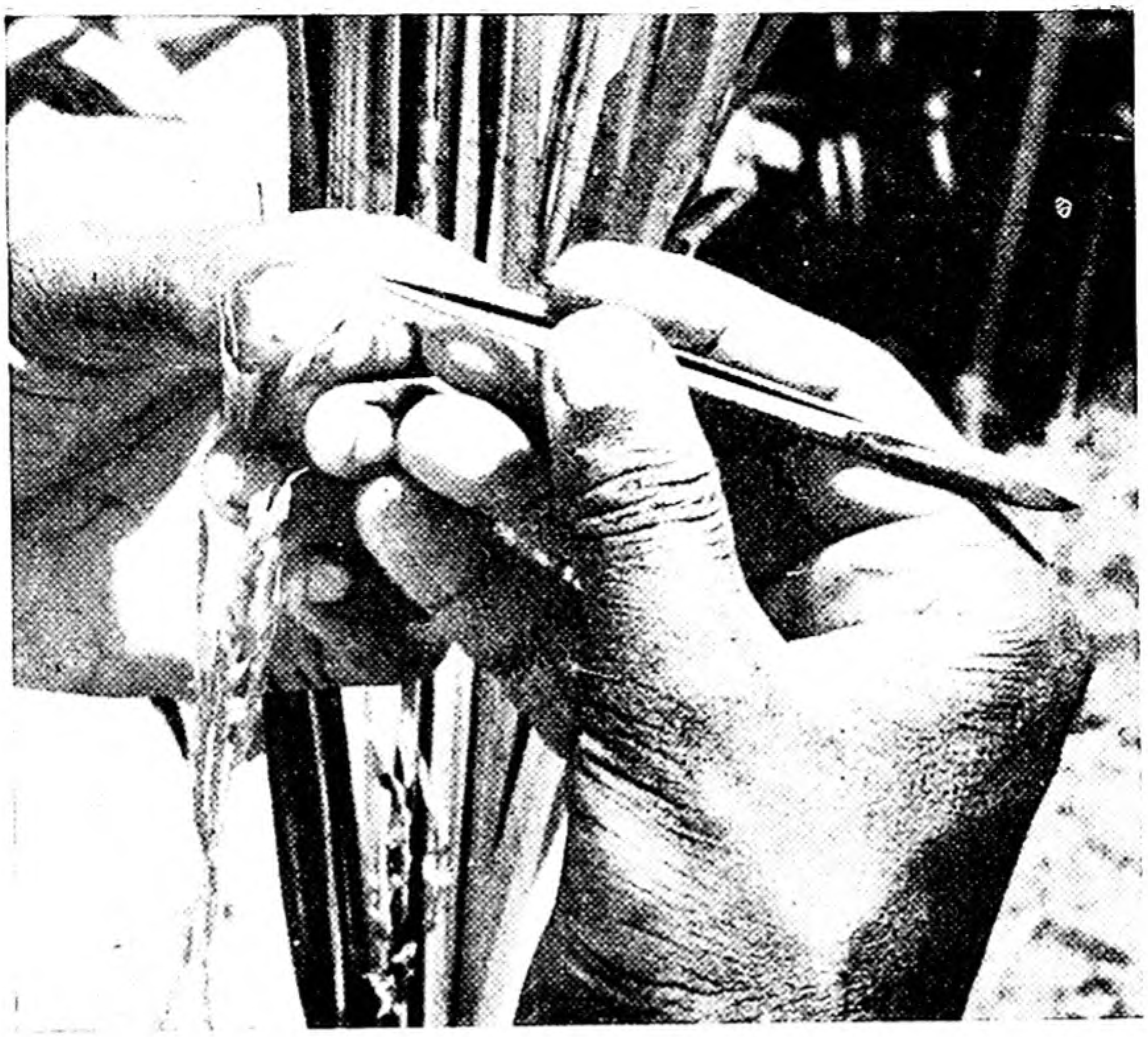


Fig. 34. Pollination of the rice flower

Fig. 35. Pollinated plants

2. Selections from introduction

Hr.19, Hr.22, Rdr.4, and *Hr.47*

Hr.19 is the most popular strain, occupying an area of 1,60,000 acres, while *Hr.35*, the next popular strain, occupies an area of 1,00,000' acres. The latter (*Hr. 35*) is a medium, finegrained strain, which gives a good out-turn of whole grain (kernels); the rice takes good polish, cooks free and tastes well. Its straw, however, is not palatable to cattle.

Madras. From this State, 113 improved strains, suitable for different soils, topographical and climatic conditions, have been released. Of these, 103 have been evolved by selection, and the remaining 10 by hybridization. These strains ripen uniformly, and give, on an average, 15 to 20 per cent. increased yield over their local bulks. While most of them are suitable for the tracts for which they were evolved, some of them have gained Statewide popularity, and still others have been found suitable for areas outside the State. A list of the strains suitable for the different regions of the State is given below:

Agricultural Regions	*List of Strains*
1. The East Coast region, the deltaic areas of the Cauvery river.	*Adt. 1* to *25*
2. The East Coast and north-east region	*Tkm. 1* to *6*, *Plr.1* to *3*
3. The central and southern region	*Co.1* to *23*, *GEB.24*, *Co. 25* to *28*, *Asd.1* to *11*
4. The West Coast region of heavy rainfall	*Ptb. 1* to *32*, *Mgl.*1 to *6* *Wnd.1* and *2*

Several of the strains evolved, besides giving high yield, also possess special characteristics like resistance to diseases, flood, drought and lodging. For example, *Co.4*, *Co.25*, *Co.26 Adt.25.* and *Tkm. 1* are resistant to Blast; *Co.14*, *Ptb. 15* and *Adt.10* can stand submersion to some extent; *Co. 17*, *Adt. 12*, *Ptb. 7* can stand drought or irregular water-supply; *Ptb.9* is non-lodging while *Co. 20* responds to heavy manuring.

Among the fine varieties, special mention may be made of *GEB. 24*, an outstanding strain of high quality, good yielding capacity and adaptability to a wide range of cropping conditions. *Tkm. 6* and *Ptb. 20* are two other strains which have wide adaptability.

Madhya Pradesh. In this State, 18 improved strains have been released. These include 10 medium and coarse-grained strains of varying durations, four fine-scented strains and four purple-leaved strains evolved by hybridization to combat the wild rice menace in rice fields.

Mysore. Twenty-five improved strains have been released from Mysore State. Some of these, like *S.661*, *S.701*, *S.749*, *S.199*, *S.718*, *S.139*, *S.317*, *S. 705*, *B.705*, *B. 1370*, *B. 281* and *S.1092*, are very popular, and are reported to cover large areas. *S.1092*, which is a selection from a cross between *Bangarkaddi* and *Coimbatore* Sanna, is profuse tillering, non-lodging and high-yielding. Some introductions from neighbouring States, like *SR.26B* from Orissa, *C.27* and *Wnd 2.* from Madras and *Hr. 39* from Hyderabad, are doing well in this State. Three Burmese and three Chinese introductions are also found suitable for certain areas.

Orissa. Thirty-four improved strains of varying duration and some of them suitable for special conditions like *pat* lands flooded areas and salt lands, have so far been released from the State, and are given below.

1. Autumn paddy	*B.76, Bam.15, J.1, T.608*
2. Early winter	*J.2, J.3, J.10, Bam.12, Bam.13, T.56, T.380* and *T.442*
3. Mid-winter	J*.4, J.5, J.6, Bam.11, Bam.14, T.141. T.412, T.812* and *T.1145.*
4. Late winter	*J.7, J.11, Bam.3, Bam.6, Bam.9. T.90, OBS.7* and *T.1242*
5. Special types	*D.1.3* and *D.1.4* for *pat* lands, *SR.26B* for saline lands
	FR 13A and *FR43B* for flood tracts

Strains *T.90, T.141* and *T.812* are fine-grained, while *J.6* and *T.412* are fine-grained and scented.

Punjab. Eight improved strains have been released from this State. Of these, four *viz., Basmati-370, Palman Suffaid-246* and, *349-Jhona* and *Sathra-278* are suitable for the plains; *Ram Jiwain-100, Phulpattas-72* and *Lal Nakanda-41* are suitable for low hills, while *Dundar-43* is suitable for high altitudes.

Basmati-370 is a long-grain, scented table variety, highly prized for its flavour and cooking quality; *Ram Jiwain-100* is a medium quality slightly-scented rice, while *Dundar-43* is a non-shattering strain.

Besides the released strains, three introductions of Chinese origin have been found to be promising for cultivation in the hilly tracts.

Travancore-Cochin (now Kerala). From this State, 14 improved strains have been released for cultivation. Of these, *Mo.1* and *Mo.2*, are popular in the *punja* areas of Central Travancore. Among the others, *Adr-10, 13, 14, 23, 26* and *36* are suitable for the *Virippu* season, and *Adr. 41, 52, 67* and *74* suitable for the *Mundakan* season. Four introductions, *Ptb.7, Ptb. 10* and *Co. 16* from Madras State have been found promising, and are being multiplied and distributed.

Uttar Pradesh. Twenty-four strains have been released from this State. Of these, eight are early, seven are of medium-duration, and the remaining nine are late-maturing.

Among the released strains, *T.1, T.3, T.12, T.23,* and *T.100* are extensively grown all over the State. Strains *N.22, N.27, N.32* and *A.64* are suitable for un-irrigated tract of eastern Uttar Pradesh, *T.17* and *T.22A* are grown in the irrigated areas, while *T.43* and *T.36* are suitable for the submontane regions. *T.3*, a selection from the famous scented Dehra Dun *Basmati* rice, is highly prized for its flavour and cooking quality.

Besides these improved strains from local varieties, two Chinese introductions *Ch.4*, and *Ch.10*, are found promising. *Ch.10* is particularly suitable for growing at high altitudes of the hilly districts, and *Ch.4* yields well with heavy manuring, and is suited for the *Terai* areas of Bundelkhand and western districts.

West Bengal. Forty-five improved strains have been evolved in this State. Besides the improved local strains, three introductions, *FR.13A, FR.43B* and *SR.26B*

from Orissa, are doing well, and are included in the recommended list of strains of the State. Among the strains, *Patni-23* (*Chin.7*) is a famous quality table rice with a foreign market. *Bankura 1, 2, 6, 13, 35* and *Chinsurah 7* are characterized by their wide adaptability to different soil and climatic conditions in the State. *Chinsurah 15, Bankura 25, Chinsurah 17, Chinsurah 39* and *Bankura 33* are fine white rices, the latter three strains being scented as well. *Chinsurah 17* and *Chinsurah 39* are suitable for making *pulaos* and *paiyes* (pudding). *Chinsurah 3, Chinsurah 6, Chinsurah 23, Chinsurah 29* and *Bankura 15* are suitable for preparing breakfast foods like puffed and pressed rice.

BREEDING FOR HIGH RESPONSE TO HEAVY MANURING

With the present emphasis on the intensive cultivation of rice and increasing use of fertilizers, there is need for strains which, besides being high-yielding, also respond well to heavy manuring so that the full benefit of the high level of fertilizer application can be realised.

Most of the cultivated varieties of rice belong to the single species, *Oryza sativa*. Within this species two major groups *viz.*, *indica* and *japonica* are recognised. The *indicas*, grown all over the tropics, are lower-yielding, and cannot generally stand heavy fertilizer application, which induces a rank vegetative growth in them, resulting in their lodging. They are, however, hardy, and adapted to tropical conditions, and several of them carry genes for resistance to some of the major diseases. The *japonicas*, on the other hand, are grown in the subtropical and warm temperate regions beyond 30°N and S latitudes. In their own habitat, they are higher-yielding than the *indicas*, as short-statured, comparatively non-lodging, and are highly responsive to heavy fertilization.

The *japonica* rices when introduced into tropical countries like India, have so far proved a failure, as the plants show very poor growth and tillering, and produce only one or two small earheads. The *japonicas* have thus been found to be unsuitable for direct introduction, but it was thought that it might be possible to utilize them as parents for incorporating their valuable characteristics into the *indicas* and develop strains which would combine the high yield and responsiveness to heavy manuring, characteristic of *japonicas* with the hardiness and adaptability to tropical conditions of the *indica* rices. With this object in view, an intensive programme of hybridization between *japonica* and *indica* rices was undertaken, under two separate projects sponsored at the Central Rice Research Institute, by the Indian Council of Agricultural Research and the Food and Agriculture Organisation of the United Nations for the benefit of the States in India and several South and South-East Asian countries, respectively.

In these two projects, 192 *indica* varieties selected by the Indian states and the several Asian countries were crossed to several *japonica* varieties obtained from Japan and in all, 710 *japonica-indica* cross-combinations were made. The seed from the hybrids of the various cross-combinations was distributed to the States in India and the participating Asian countries for growing the F_2 and subsequent generations or further breeding work under the environmental conditions prevailing in the tracts where the improved strains were scheduled to be ultimately grown.

The F_1 generation of the various cross-combinations was studied at the Central Rice Research Institute. The hybrids showed considerable heterosis, particularly for the tiller number. In duration they were intermediate between the parents, and in height as tall as the larger parent (*indica*). Table 12 gives some examples of the performance of the hybrids.

TABLE 12. PERFORMANCE OF HETEROSIS IN *japonica-indica* HYBRIDS

Cross-combination	No. of ear-bearing tillers			Height (cm.)			Flowering duration (day)		
	Mid-parent	*F_1 value*	*F_1 increase over mid-parent per cent.*	*Mid-parent*	*F_1 value*	*F_1 increase over mid-parent per cent.*	*Parent*	*Japonica parent*	*F_1 indica*
Norin 6×Adt. 18	7.9	22.5	184.8	93.0	124.4	33.8	100	65	84.0
Norin 18×S. 22-Latisal	8.6	25.8	200.0	88.2	125.8	42.6	120	73	82.0
Asahi×S. 22-Latisal	6.5	19.6	201.5	90.4	120.3	33.1	120	67	87.3

The hybrids exhibited varying degrees of spikelet sterility, ranging from 10 per cent. to over 99 per cent. with a large number of cross-combinations having 50 to 70 per cent. sterility. The frequency distribution for spikelet sterility is given in Table 13.

TABLE 13. STERILITY IN *japonica-indica* HYBRIDS

Sterility per cent.	No. of cross-combinations
11—20	1
21—30	11
31—40	24
41—50	46
51—60	57
61—70	74
71—80	61
81—90	57
91—100	32

A study of the F_2 generation of three cross-combinations with low (25 per cent.), medium (50 per cent.) and high (80 per cent. sterility in the F_1 hybrid showed that the variance and mean sterility percentage of the F_2 were of the same order in all the three families, as shown in Table 14.

TABLE 14. STERILITY IN F_1 AND F_2 GENERATIONS OF *japonica-indica* CROSSES

Cross-combination	F_1 sterility per cent.	Mean sterility per cent.	Variance sterility F_2	C.V. F_2	Per cent. of plants in F_2 below 50 per cent. sterility
MO$_1$ × *Taihoku*-6	25.0	52.7	378.4	37.0	49.8
Asahi × *Wanner*-1	47.8	53.2	519.4	42.9	54.1
T. 1145 × *Taihoku*-6	79.6	49.8	384.1	39.4	60.9

From the behaviour of the F_1 it was concluded that the sterility of the hybrids need not be a handicap in the breeding project, as equally good fertile selections could be obtained from highly sterile hybrids as from more fertile ones. This view was confirmed from the behaviour of the later generations, where the dispersion of low, medium and high sterility groups was more or less the same and good-yielding fertile solutions could be obtained from different cross-combinations irrespective of their F_2 sterility, as shown in Table 15.

Fourteen *japonica-indica* cross-combinations in the F_3 generation were studied under normal manuring (40 lb. N+18 lb. P_2O_5 per acre) and heavy manuring (70 lb. N+36 lb. P_2O_5) for 11 quantitative characters, at the Central Rice Research Institute (Tiwari 1957). Results are given in Table 16.

Results show that there was an increase in the plant height, the number of ear-bearing tillers per plant, ratio of ear-bearing tiller to total tillers per cent., spikelet sterility per cent. yield of grain per plot and per plant and the protein content of the hybrids over their respective *indica* parents, the increase being 4.6, 72.7, 48.5, 13.8, 37.6 and 11.5 per cent. respectively, under heavy manuring and 5.0, 61.1, 51.0, 3.6, 24.3, 24.3 and 11.5 per cent. respectively under normal manuring. There was a decrease in the total tillers per plant, flowering duration, 500 grain-weight, straw weight and ratio of straw-grain in the hybrids over their *indica* parents at both the levels of manuring. Between the two levels of manuring, the performance of hybrids under heavy manuring was in general superior to that under normal manuring in the first set of characters enumerated above. Under heavy manuring, the number of high-yielding selections were 22.4 per cent. more than those obtained under normal manuring. The average single plant yield of selection in the former was 10.3 per cent. higher than that in the latter. Compared to hybrid cultures, the *indica* parents, under heavy manuring, showed a very small increase over normal manuring in most of the characters except straw yield and ratio of straw to grain, where the increase was 22.2, 31.2 and 31.1 per cent. respectively.

The selections made in the several *joponica-indica* cross-combinations are now in various breeding stages at the Central Rice Research Institute and in the States. At the Institute, some of the selections in advanced filial generations were tested under two levels of manuring in small bulk trials. Several of these cultures yielded 18 to 34 per cent. significantly more than their respective *indica* parents at both the levels of manuring. The cultures were also earlier maturing.

TABLE 15. PERFORMANCE OF SELECTIONS IN THE *Japonica-indica* CROSSES FROM F_1 TO F_6

Serial No.	*Cross-combination*	F_1 generation		F_2 generation			F_3 generation			F_4 generation			F_5 generation			F_6 generation		
		Indica parent mean single plant yield (gms)	*Sterility per cent.*	*No. of selections*	*Mean single plant yield (gms)*	*Per cent. of sterility*	*No. of selections*	*Mean single plant yield (gms)*	*Per cent. of sterility*	*No. of selections*	*Mean single plant yield (gms)*	*Per cent. of sterility*	*No. of selections*	*Mean single plant yield (gms)*	*Per cent. of sterility*	*No. of selections*	*Mean single plant yield (gms)*	*Per cent. sterility*
1.	*GEB* 24 × *Norin* 1	21.2	63.4	51	30.1	30.8	41	56.0	27.2	45	55.1	25.5	5	44.6	17.2	5	45.6	19.6
2.	*GEB* 24 × *Norin* 6	21.2	73.7	24	31.3	36.8	25	56.6	25.5	34	55.6	24.3	3	57.3	18.3	3	51.0	18.5
3.	*GEB* 24 × *Norin* 23	21.2	68.3	5	40.2	31.7	17	45.7	26.8	10	46.0	22.5	4	49.0	21.8	4	50.2	22.2
4.	*GEB* 24 × *Rikku* 132	21.2	68.1	36	37.0	35.6	35	48.0	26.3	19	51.9	22.7	19	51.4	22.8	1	55.0	20.2
5.	*GEB* 24 × *Taihoku* 6	21.2	73.0	22	42.9	40.2	21	46.8	28.7	23	50.7	27.3	5	50.2	17.0	3	61.0	18.6
6.	*T* 90 × *Aikoku*	20.5	65.4	18	38.6	34.6	16	41.5	29.5	8	50.4	17.9	2	53.5	23.7	1	53.0	11.1
7.	*T* 90 × *Taichu* 65	20.5	60.2	2	22.5	39.8	11	71.3	27.6	5	63.0	26.8	2	58.5	25.5	2	75.0	14.5
8.	*T* 1145 × *Asahi*	27.4	77.6	23	38.8	28.1	37	45.9	23.4	23	53.3	19.5	10	53.7	21.4	9	72.1	21.8
9.	*T* 1145 × *Taihoku* 6	27.4	80.9	40	34.6	47.8	55	48.3	23.5	38	51.4	18.9	28	56.6	19.6	11	73.1	16.1
10.	*Bam* 9 × *Norin* 18	29.0	55.2	43	32.5	29.7	54	55.1	20.5	23	56.9	16.0	19	55.7	20.6	8	66.8	20.2
11.	*Bam* 11 × *Taihoku* 6	31.8	32.0	20	42.2	21.9	39	47.4	21.5	18	57.1	20.0	7	51.3	22.3	5	61.8	16.2
12.	*Bam* 11 × *Asahi*	31.8	27.4	19	34.6	19.5	21	44.7	20.2	14	57.1	15.4	7	54.0	17.6	4	70.0	15.3
13.	*Patnai* × *Rikku* 132	18.3	69.7	18	31.2	39.2	28	41.8	23.2	12	62.6	18.5	9	50.3	20.3	2	88.7	14.8
14.	*HS* 19 × *Taihoku* 6	22.8	62.4	7	31.9	35.8	20	57.4	23.7	18	55.4	21.5	9	60.1	25.0	11	63.0	17.6

Table 16. Performance (Mean Values) of Various Characters of Several *Japonica—indica* Cultures in the F_3 Generation, Under Normal and Heavy Manuring Conditions

Character	Indica parent			Cross-combinations			Per cent. increase of crosses	
	Normal manuring (N.M.)	*Heavy manuring (H.M.)*	*Per cent. increase of H.M. over N.M.*	*Normal manuring (N.M.)*	*Heavy manuring (H.M.)*	*Per cent. increase of H.M. over (N.M.)*	*Normal manuring (N.M.)*	*Heavy manuring (H.M.)*
1. Plant height (cm.).	125.8	136.2	8.3	132.1	142.4	7.8	5.0	4.6
2. Total tillers per plant	22.6	24.2	7.0	19.4	23.5	21.1	—14.2	—2.9
3. Ear-bearing tillers per plant	5.4	6.6	22.2	8.7	11.4	31.0	61.1	72.7
4. Ratio of E.B.T.* to total tiller (per cent.). ..	30.0	33.0	10.0	45.3	49.0	8.1	51.0	48.5
5. Flowering duration (days).	135.5	138.2	2.0	110.1	112.0	1.7	—18.8	—19.0
6. 500 grain weight (gm).	13.6	13.4	1.4	12.5	12.4	—0.8	—8.1	—7.4
7. Spikelet sterility per cent.	28.0	28.3	1.0	29.0	32.2	11.0	3.6	13.8
8. Yield of grain per plot (Oz.).	10.7	10.9	1.8	13.3	15.0	12.7	24.3	37.6
9. Yield of straw per plot (Oz.)	33.6	44.1	31.2	33.3	35.0	5.1	—0.9	—20.6
10. Ratio of straw to grain	4.5	5.9	31.1	2.7	3.0	11.1	—40.0	—49.2
11. Single plant yield of grain (gm.).	8.4	8.6	1.7	10.5	11.8	12.7	24.2	37.6
12. Protein content	6.5	7.0	8.0	7.1	7.8	11.4	9.3	11.5
13. No. of single plant selections carried forward. ..				58	71	22.4		
14. Mean S.P. yield of selections (gm.). ..				29.0	32.0	10.3		

*E.B.T.—Ear-bearing tillers per plant.

Reports received from Andhra Pradesh indicate that a number of high-yielding cultures possessing fertilizer response, non-lodging and non-shattering habit have been isolated.

In Bombay State, promising selections, combining high yield, non-lodging habit and other desirable characters are reported to be on hand.

In Kashmir State, a number of F_4 and F_5 cultures which are non-shedding and yielding 25 to 45 per cent. more than the local standard, have been isolated.

In Madras State, a number of fully fertile cultures combining good tillering and non-lodging habit have been obtained. Several of these cultures have been found to be responsive to heavy manuring.

In Orissa State, selections combining high yields, earliness, short stature and high tillering capacity are reported to be doing well, particularly at the Jeypore Rice Research Station.

In the Punjab, about 200 progenies in the F_5 stage, which combine the high response to fertilization and short stiff straw of the *japonica* with the desirable agronomic characteristics of the *indica* parent are undergoing small-scale trials.

In Uttar Pradesh, at the Rice Research Station, Nagina, 24 of the selections were tested in a preliminary yield trial and three selections were found superior to the standard *Ch.4*, while nine were found superior to the second standard., *T.21.* One of the selections gave over 3,000 lb. of paddy per acre. At the Gorakhpur Sub-station, two selections were found superior to the standard varieties, *N.22.*, *T.136* and *Sarya local*

In West Bengal, several cultures in F_4 and F_5 generations are reported to yield 12 to 13 per cent. more than the *indica* parent and are also responsive to manuring.

BREEDING FOR EARLINESS

A large number of early maturing varieties are grown in different parts of India, as for example, the *kar* and *kuruvai* varieties of Madras, the *beali* varieties of Orissa, the *aus* varieties of Assam and West Bengal etc. The early-maturing varieties are of special importance for tracts with low and uncertain rainfall or tracts where the growing season is short due to the early setting in of low temperatures, such as Kashmir and the Kulu valley, or for tracts which are subject to drought, as well as for tracts where double cropping of rice is practised. Early-maturing rices are also in demand in areas where rice is followed by a cash crop like the potato. Unlike long duration varieties, most of the early-maturing varieties take more or less the same number of days to mature, irrespective of the season during which they are grown, and as such they are adapted to a wider range of sowing. Earliness is a valuable character, provided it is not associated with loss in yield. Each State has evolved good-yielding, early-maturing strains to suit the varying local conditions. However, there is need for intensifying the breeding programme for evolving early and still higher yielding strains. This is also important if the irrigation water which would be available shortly on the completion of the new multi-purpose projects, is to be put to maximum use.

At the Central Rice Research Institute, cultures combining high yield and

early maturity have been evolved from crosses between local Orissa types and early maturing Chinese types and *Sathika* (a local early variety). The performance of some of these promising cultures was tested at three centres *viz.*, Cuttack (Orissa), Chinsurah (West Bengal) and Trichur (Kerala). Several of these cultures were found to be significantly superior to the control, with different cultures doing better at different centres. However, one culture, *viz.*, *T. 1145* × *Ch. 2-42-76-95-2*, was superior to the control at all the three centres, yielding 14.5, 18.5 and 27.8 per cent. more than the control, at Chinsurah, Trichur and Cuttack, respectively. The yield per acre of the control at Chinsurah, Trichur and Cuttack was 2,451, 1,463 and 2,412 lb. respectively. All the cultures flowered within 90 days of sowing.

In Assam State, three very early-maturing (80 to 93 days) strains, *D.204*-1, *M.142* and *C.203* and five early strains (100 to 110 days), *As.2*, *As.3*, *As.24-1*, *As.48* and *As.86* have been released. One of these, *As.* 24-1 is a fine grained strain.

Six early strains have been released from Andhra Pradesh. These are *Slo.16*, *Slo. 19*, *Mtu.9*, *Mtu.15*, *Mtu. 18* and *Mtu.20* and *Pla. 1*. Of these *Slo. 10*, *Mtu. 9, 15* and *Pla. 1* are specially suitable for the second crop, while *Mtu.20* is suitable for both the first and second crops. *Slo. 16*. and *Slo. 19* are also fine-grained.

In Bihar, five early strains, *Br.1*, *Br.9*, *Br.21*, *Br.22* and *Br. 24* have been released. These take 95 to 112 days to mature. *Br.9* and *Br.21* are suitable for the second crop, while *Br. 24* is a good ratooning strain. *Br. 1* is a fine, long grained rice.

In Bombay, nine early strains maturing within 120 days have been released. Among them, *Early Kolpi-70*, *Kolamba-184* and *Early Ambemohar-102* are fine-grained rices. Four early Chinese varieties have also been reported to be doing well.

Four early strains, *Rdr.2* *Rdr.7*, *Hr.12* and *Hr.19*, have been released from Hyderabad State. (now in Andhra Pradesh.)

Madhya Pradesh has evolved three early strains, *viz.*, *R.2 Nungi* (No. 17) *R.3 Sultugurmatia* and *R. 10 Chattri*. The first two are suitable for upland and rain-fed areas. *R. 10 Chattri* is a fine scented rice.

In Madras State, a large number of early strains have been released. Some of the more important ones are *Co.9*, *Co.13*, *Co.20*, *Adt.*3, *Adt.4*, *Adt9*, *Adt.16*, *Adt.19*, *Adt.20*, *Asd.1*, *Asd.2*, *Asd.7*, *Asd.8*, *Asd.9*, *Ptb.10*, *Ptb.23*, *Ptb.24*, *Ptb.25*, *Tkm.5* and *Tkm.6*. They take from 95 to 120 days to mature, and yield between 3,000 to 4,000 lb. of paddy per acre. *Co.9* has red rice; *Co.20* responds to heavy manuring.

In Mysore, *S.705* is an early-maturing (115 days) strain, which is fairly drought-resistant also. Some of the early Chinese varieties, like *Ch.2*, *Ch.45* and *Ch.47* are reported to be suitable for areas with limited water facilities.

There are six early strains evolved in Orissa. These are *B.76*, *J.1*, *J.2*, *Bam.12*, *Bam.13*, *Bam.15* and *T.56* *J.1* is fine-grained and suitable for the hill tracts.

Of the 24 improved strains evolved in Uttar Pradesh, 12 are early strains, maturing within 115 days. Among them, *T.136* and *T.1 Ram Jiwain* are finegrained rices. *T.136* is grown extensively in the eastern and western districts.

BREEDING FOR DEEP WATER AND FLOOD RESISTANCE

There are considerable areas in certain parts of India, notably in Assam, West Bengal, Western India, Orissa, Madras, Kerala and Andhra Pradesh which get flooded to varying depths of water. In Assam, the flood waters may rise 15 to 20 feet during the months of June-July, and the fields may continue to remain submerged for a long time. Along the sea coast, besides flood water, the rice-grower has to contend with salinity as well. In the ill-drained areas of the interior, the floods may not be a regular feature, but may occur in year of excessive rainfall. Thus, the problems of each flooded area are peculiar, and need to be studied.

Varietal differences, with regard to capacity to withstand submersion for a particular length of time and the capacity of plants to grow fast with the rise of water and thus keep above the surface have been noted, and, therefore, States afflicted with the problem of floods have taken up programmes of breeding suitable varieties.

In Assam, at the Deep Water Paddy Station, Habibganj (now in Pakistan), four long-stemmed strains, *Hbj.1*, *Hbj.2*, *Hbj.3* and *Hbj.4* were evolved. The strains could grow in 5 to 7 ft., 8 to 10 ft., 10 to 14 ft., and 8 to 10 ft. of water, respectively, and yield higher than the local varieties. At the new research station at Rohu, a programme of selection and hybridization for the evolution of high-yielding deep water and flood-resistant varieties has been taken up. Two strains, *E.B.1* and *E.B.2*, which can stand 10 to 15 ft. and 8 to 10 ft. of water respectively, have been isolated, and are under trial. Three strains of *bao* rice, *Ar.1.*, *Ar.C.353-148* and *Ar. 614-250*, which can stand 2 to 6 ft. of water have been released from the Karimganj Research Station.

Work is in progress on the evolution of flood-resistant varieties at the Deep Water Rice Research Station at Pulla in Andhra Pradesh. Work so far done has brought to light a variety (an introduction from Burma) which can withstand intermittent flooding up to 3 ft., and a variety, *Ar. 108*, which can stand continuous flooding, varying from 4 to 6 ft. A selection, *DWP-1311* obtained from a cross between *Mtu.16* and *Ptb.15*, is promising. This selection can withstand flooding up to 3ft.

In Madras, three strains have been found to withstand submersion to some extent. *Co.14*, yielding 3,000 to 4,000 lb. per acre is reported to stand submersion to a depth of 3 to 4 ft. if sown early. *Adt. 17*, yielding 3,700 lb. per acre, can also stand submersion to some extent. *Ptb. 15*, yielding 3,000 lb. per acre is suitable for growing in submersible areas.

Three districts of Orissa—Puri, Cuttack and Balasore—are liable to be inundated in the lower regions of the delta. Several flood-resistant strains, *FR.2*, *FR.4A*, *FR.13*A, *FR.27A*, *FR.35A*, *FR.43B*, *FR.44A*, and *FR.44B* were isolated by pure line selection from among the surviving plants in the flood-affected areas. Of these, *FR. 13A* and *FR.43B* were released as flood resistant strains. *FR.43B* is reported to have the characteristic of regeneration by secondary tillering even after all the primary tillers perish in the flood.

In West Bengal, two flood-resistant strains of Orissa, *FR.13A* and *FR.43B*, locally called *Chin.41* and *Chin*.43 respectively, have also been found suitable. *Hybrid 84* (from *AS. 108*/1 × *Patnai* 23) is reported to be fairly resistant to flood with capacity to stand 6 ft. of water.

BREEDING FOR RESISTANCE TO SALINITY AND ALKALINITY OF SOIL

The coastal areas in Andhra Pradesh, Bombay, Madras, Kerala, Orissa and West Bengal are subject to salt water inundation. In the Punjab and Hyderabad (now in Andhra Pradesh), while there is no problem of inundation from sea water, there are tracts with alkali soils where rice is grown. In the coastal regions, due to the low-lying nature of the land, the areas remain submerged by tidal waters during certain seasons of the year, and hence, besides breeding for salt-resistance, the varieties evolved must be flood-resistant also.

Breeding for saline resistance is in progress in several States. Andhra Pradesh has an area of about 0.15 million acres under salt land. A research station was opened at Masulipatam in March, 1954. A project financed by the Indian Council of Agricultural Research, for evolving saline-resistant varieties suitable for saline areas along the east coast and inland pockets, is in progress at this Station. Several varieties and hybrid cultures were tested in 1954-55 and 1955-56, for their resistance to salinity., It was found that two hybrid cultures from the cross *Mtu.1* × *SR.26B* were more resistant than others, while type *No.892* and variety *Kuthir* appeared promising. A number of crosses were made between these two types on the one hand and nine other varieties as parents on the other to combine high yield with saline-resistance. The selected cultures are under study. A further programme of hybridization between saline-resistant varieties and good quality varieties has been taken up.

A station was established in Sandakud near the sea in Orissa for testing salt-resistant varieties. Thirty-nine promising lines were isolated from the material collected from various saline tracts of the State and also from types obtained from outside the State, and finally, three resistant strains, *SR.8* (early maturing) *SR.14* and *SR.26B* (medium duration) are reported to have been released.

In Bombay, a station was opened at Panvel (Kolaba District) in 1943 to take up improvement work on the major salt land rice varieties which are grown over an area of 0.15 million acres along the sea coast. Promising selections have been isolated from *Kala Rata, Bhura Rata, Morchuka, Dodka* and *Khara Bhat.* Two selections, *Kala Rata 1-24* and *Bhura Rata 4-10* giving about 10 per cent. higher yield than the local varieties have been released. Promising cultures, combining good yield and saline-resistance, obtained from crosses between good-yielding sweet land varieties from Karjat and local salt land varieties, are under advanced stages of study.

About 0.2 million acres of rice land in Madras State are saline. More than 30 varieties of local importance were tested for their resistance to salinity, and two varieties, *SR.26b* from Orissa and *T.892,* were found to be fairly resistant. Crosses between these two varieties on the one hand and the high-yielding Coimbatore strains on the other were made, and some of the cultures have been found to be quite promising.

Work is in progress in West Bengal to evolve strains resistant to salinity. Results so far indicate that two varieties, *Kumargore* and *Bokra,* are promising. These are being tested in large scale trials. Two improved strains, *Chin.13* and *Chin.19* are stated to be salt-tolerant. The salt-resistant strain *SR.26B.* from Orissa has been introduced in the State.

In Hyderabad, 336 varieties were tested for tolerance to alkalinity (*p*H 8.5 to 9.0) and 54 of them were found tolerant. Further work is in progress.

BREEDING FOR DROUGHT-RESISTANCE

Most of the rice cultivation in India is dependent upon rainfall, only a small percentage being under irrigation. Large areas of land receive very little or an erratically distributed rainfall, and these areas are constantly under the threat of crop failure, due to the drought conditions created by the failure of rains or due to insufficient precipitation. The problem of evolving drought-resistant varieties for such areas has been receiving attention of breeders in the different States of India.

It has been observed that certain varieties grown under restricted conditions of water-supply thrive better than others, and this would show that the capacity to resist conditions of drought is genotypic and governed by specific genes in the varieties concerned. It should, therefore, be possible to transfer genes for resistance to otherwise desirable varieties, and obtain good-yielding, drought-resistant strains. Work in this direction is in progress in some of the States.

Among the improved strains evolved in Andhra Pradesh, *Akp.1*, *Akp.2*, *Bcp.2* and *Bcp.5* are reported to be drought resistant, while *Pla.1*, is slightly resistant to drought.

In Madras State, about 0.4 million acres of rice are grown under rain-fed conditions. Breeding of drought-resistant varieties has been taken up under a scheme partly financed by the Indian Council of Agricultural Research. Over 700 progenies, obtained from crosses among rain-fed varieties and between rain-fed varieties on one hand and wild rices on the other, are now under study at the Coimbatore, Pattambi (now in Kerala) and Tirukuppam research stations. Among the improved strains evolved by the States *Asd.4* and *Ptb.18* are reported to be drought-resistant, while *Asd.8* and *Asd.9* are suitable for high lands with precarious rainfall.

In Orissa, *Bam. 15* is reported to be resistant, and *Bam.12* and *Bam. 14* moderately resistant to drought.

In Uttar Pradesh, in order to evolve early drought-resistant strains, some of the high-yielding varieties have been crossed to early Hungarian and Russian varieties, and some of the hybrids are under trial. Among the improved strains, *N.22 Rajbhog*, *N.32 Buljati* and *A.64 Hansraj* are reported to be drought-resistant.

Two improved strains, *viz.*, *Chin* 25 and *Chin*. 27 of West Bengal have been found to be resistant and moderately resistant to drought respectively.

BREEDING FOR RESISTANCE TO LODGING

The lodging of the crop is a serious problem affecting rice production in India. Almost all the Indian varieties are weak-strawed, and are prone to lodging when heavily manured. With the present drive for intensive cultivation, there is need for growing non-lodging and stiff-strawed varieties, which can make full use of heavy manuring.

Preliminary investigations conducted at the Central Rice Research Institute on the loss in yield due to lodging at different stages of plant growth have shown

that there is 60 per cent. loss in yield when the crop lodges at the pre-flowering stage. The loss is reduced as lodging is delayed, and at the dough and ripening stages, the loss is about 18 per cent. The lodging of the crop comes in the way of increased production and breeding for strong straw is, therefore, a necessity.

With this object in view, the large collection of world genetic stocks at the Central Rice Research Institute is being tested for yield and non-lodging habit and heavy manuring and low-lying conditions. Among the varieties tested, *AC 1951*, a medium duration variety has proved to be non-lodging and good-yielding, the *bulus* of Indonesia and *Vary lava* varieties of Madagascar and some up Siamese and Burmese have also been found to be stiff-strawed. Most of the non-lodging types, however, are very late-maturing and low-yielding, and are, therefore, being utilised for crossing with the high-yielding and weak-strawed Indian varieties.

Among the improved varieties evolved by the different States, the following are reported to be non-lodging.

Assam	—	*Sc. 1177-6*
Andhra Pradesh	—	*Mtu.3, Mtu.7, Mtu.10, Mtu.14, Mtu.19, Akp.9, HR.21*
Bihar	—	*Br.8*
Bombay	—	*Bhadas-79, Garvel-1-8*
Madhya Pradesh	—	*Budhiabako, Luchai* × *Gurmatia* × *Burma No. 2* and *Nungi* × *Nagkesar No. 1* are moderately resistant to lodging.
Madras	—	*CO. 4, CO. 15, CO. 17, Ptb. 9, Ptb. 15, Asd. 6*
Mysore	—	*S. 1092*

BREEDING FOR NON-SHEDDING OF GRAIN

The shedding or shattering of grain from the ear at the time of harvest is one of the important factors contributing to loss in yield of rice. This problem assumes special importance in areas of extensive cultivation, where harvesting continues over long periods. While a certain amount of mechanical shedding is inevitable and desirable (so as to facilitate threshing), the aim of the breeder should be to limit shedding to the minimum.

While most of the improved strains evolved possess a certain amount of shedding, there are some strains which shatter to a greater extent, and some others are practically non-shedding.

In Kashmir, shedding is a serious problem, as the rice varieties, particularly the popular high-yielding Chinese introductions which have spread widely in the State, are prone to shed grain badly. Work is in progress to breed non-shedding, high-yielding strains and some recent introductions of Chinese and Japanese rices are reported to be very satisfactory from these points of view. Some cultures from *japonica—indica* crosses in the F_4 and F_5 generations, which combine non-shedding habit with good yield, are reported to have been isolated.

Among the improved strains evolved in different States, the following are reported to possess a non-shedding character also.

Assam	— *S. 22*
Andhra Pradesh	— *Mtu.7*
Madhya Pradesh	— *Luchai* × *Gurmatia* × *Burma*
Madras	— *Ptb. 9*, *Co.* 12 and *Geb.* 24

As reported earlier in this chapter, Andhra Pradesh has reported the isolation of non-shedding, high-yielding cultures from *japonica-indica*, crosses.

BREEDING FOR DORMANCY OF SEED

Most early-maturing rice varieties in India lack dormancy, and, therefore, under wet weather conditions at the time of ripening, the seeds begin to sprout while still on the panicles. This results in a considerable loss in yield and reduces the quality of grain for seed purposes. Dormancy is, therefore, a desirable character for short duration varieties. In Madras State, some of the early varieties from Iraq and Italy possessing dormancy have been crossed to some high-yielding early Indian varieties of the State. The progenies of these crosses are being studied at three centres, *viz.*, Coimbatore, Aduthurai, and Pattambi (now in Kerala State).

BREEDING VARIETIES FOR CONTROL OF WILD RICE

In some States like Bihar, Bombay, Madhya Pradesh and the Punjab, rice fields are infested with wild rice. *O. sativa* var. *fatua*. As the wild rice cannot be distinguished from the cultivated one until ears appear, considerable loss in yield occurs in such areas. The presence of wild rice in the field is a constant source of contamination, as it crosses freely with the cultivated rice. To combat this menace, purple-pigmented varieties have been evolved. The wild rice as well as the hybrids with wild rice which are green-leaved are easily identified and rogued out in the early stages.

In Bihar, two fully pigmented strains, *Br.11* and *Br.12* have been bred.

In Bombay, *Antarsal* strains with coloured leaf sheath and *Mugad* strains with green leaf sheath are grown by cultivators in alternate years so as to facilitate roguing out of *gonag* (wild rice) from the rice fields.

In Madhya Pradesh, *Nungi* × *Nagkesar No. 1* (completely purple-pigmented) and *Luchai* × *Nagkesar No. 1* × *Luchai No. 18* have been released.

In the Kangra hills of the Punjab, the loss in yield due to wild rice in the cultivated fields has been estimated to be about 10 per cent. In order to combat this menace, purple-leaved rices, as in Madhya Pradesh, are being evolved.

BREEDING FOR DISEASE-RESISTANCE

The loss caused in production by disease is most effectively checked by the breeding of resistant strains. Work on breeding such strains is in progress at the Central Rice Research Institute and various research stations, particularly in Madras, Bombay and Andhra Pradesh. An account of the work being done on this problem is dealt with elsewhere.

CHAPTER 11

GENETICS

The rice plant offers a wealth of material for genetical studies, as the variations encountered in both the morphological and physiological characters are enormous. Genetical investigations of rice started with the study of the inheritance of grain colour by Van der Stok (1908) in Java. Since then, the study has been persued in several countries, notably India, Japan and the U.S.A. More than 300 genes, affecting about 50 plant characters, have been identified and their mode of inheritance followed. While in the early stages the studies were mainly confined to the inheritance of qualitative characters, they have since been extended to quantitative and physiological characters as well. Matsura (1933), Jones (1936), Jodon (1948), Kuang (1951), Nagao (1951) and Ramiah (1953a) have summarised the genetical work on rice. The review by Ramiah deals principally with the work done in India. Hutchinson and Ramiah (1938) have standardised the description of rice plant parts and a system of gene symbolisation, based on the model adopted in maize genetics, was proposed by Kadam and Ramiah (1943). Nagao (1951) has, however, suggested an alternative scheme of gene nomenclature, and an agreed international system of gene symbolisation in rice, therefore, is yet to be evolved.

ANTHOCYANIN PIGMENTATION

The occurrence as well as distribution of anthocyanin pigmentation in the organs of the rice plant is very variable, and is a very striking feature of the crop. The plants range from fully green to fully pigmented in all parts, with intermediates having pigmentation present in only one, two or more parts. The genetics of anthocyanin pigmentation in rice has attracted keen interest of the workers in India, and considerable attention has been paid by them to the inheritance of pigmentation in individual plant organs. According to Ramiah (1935), anthocyanin pigmentation, though unimportant by itself, does occasionally show genetic association with such important characters as spikelet sterility, vigour and even yield.

According to Parnell *et al.* (1917) from Madras, the expression of anthocyanin pigment in any part of the plant is governed by two complimentary genes. This view is supported by workers from Japan and the U.S.A. These two basic genes are designated as A and C by Kadam and Ramiah (1943). These genes correspond to the chromogen base and oxidizing enzyme, respectively. Different workers in India have reported different F_2 segregations like 3:1, 15:1, 9:7, 27:37, 45:19, 81:175, 162:94 etc., for the presence of pigment to its absence in the same plant part. From the investigations reported, Ramiah (1953a) concludes that besides the basic genes, there are other genes which localise the pigmentation in particular organs. He also considers that besides these, there are genes for intensifying or diluting the pigment and for producing various pigment patterns. According to him, two to seven genes are probably involved in the production of different types of pigmentation in the various organs as shown below.

Plant organ	Probable number of genes
1. Leaf-sheath	5
2. Internode	3 to 5
3. Junctura	2
4. Auricle	2
5. Ligule	3
6. Leaf-axil	2
7. Pulvinus	2
8. Septum	2
9. Glume	2 to 3
10. Lemma and palea	4 to 5
11. Apiculus	4 to 5
12. Stigma	5 to 7
13. Leaf-blade	3
14. Awn	3

Studies on the inheritance of pigmentation in rice have been mostly confined to the presence or absence of pigment in individual organs and the number of genes involved in the expression of pigmentation in these organs ; and although an intensive work has been done in this direction, there is very little critical information available on the inter-relationship of these genes. This investigation has now been undertaken at the Central Rice Research Institute, Cuttack.

Hector (1922 a), working in Bengal, has reported association between purple apiculus and colour in (i) leaf-sheath, (ii) leaf-sheath and stigma, (iii) leaf-sheath, stigma and internode, (iv) glume, lemma-palea, leaf-sheath, internode, junctura and auricle and (v) stigma and internode. Close association between the pigment in the internode and lemma-palea and between leaf-axil and stigma has been reported by Parnell *et al.* (1917), Ramiah (1953a) in one cross obtained a 3 :1 segregation for presence of colour to its absence in a large number of organs, as if a single gene was responsible for the expression of pigment in these various parts. Such associations have been observed in the large varietal collections maintained at the rice research stations in India and are detailed below.

Ramiah (1945) studied the distribution of pigment in 13 organs of the plant among the 1,100 types maintained at Coimbatore (Madras). He found that 446 of these showed pigment in some organ or the other, and formed 108 groups. While some groups occurred in large numbers than expected, certain others either did not occur at all, or occurred very rarely. The group most largely occurring was the one with pigment in six parts, *viz.*, leaf-sheath, pulvinus, septum, leaf-axil, stigma and apiculus. The next three largely occurring groups were those with pigment in (a) seven parts *viz.*, leaf-sheath, internode, pulvinus, septum, leaf-axil, stigma and apiculus, (b) in five parts, *viz.*, leaf-sheath, pulvinus, leaf-axil, stigma and apiculus, (c) in four parts, *viz.*, leaf-sheath, leaf-axil, stigma and apiculus.

Hector (1922a), taking the pigment in 11 plant parts into consideration classified 211 pigmented types of Bengal and recorded 51 groups. Of these, the three most widely occurring were (i) pigment in two parts, *viz.*, leaf-sheath and apiculus (ii)

in the three parts, *viz.*, leaf-sheath, internode and apiculus or (iii) leaf-sheath, apiculus and stigma. Jones (1929) from the U.S.A., studied the distribution of pigment in 311 pigmented types, obtained from Japan, Korea, China, Java and the Philippines and grown in America. He could classify these types into 48 groups acccording to the presence of pigment in 11 parts. According to Jones, the four most largely occurring groups in order of their frequency were (i) pigment in three parts, *viz.*, glume, apiculus and awn, (ii) pigment in two parts *viz.*, apiculus and awn and (iii) glume and apiculus, and (iv) pigment in four parts, *viz.*, glume, apiculus, awn and stigma.

Ramiah (1953 a) reviewing the distribution of pigmentation in the pigmented types maintained at Madras, Bengal and the U.S.A. found that the types of association in Bengal and the U.S.A. were different in spite of the fact that 10 of the morphological parts considered by Hector (1922 a) and Jones (1929) were the same. The only common feature he found between the two was the association between pigment in the apiculus and in the stigma.

Taking the occurrence of pigment in nine morphological parts common to the types reported from Madras, Bengal and the U.S.A., Ramiah was able to divide the 442 types of Madras into 58 groups, the 211 types of Bengal into 34 groups and the 281 types of the U.S.A. into 32 groups. The 934 types fell into 90 pigment groups, and the following three definite groups of associations were noted by him.

1. Madras—one group showing pigmentation in auricle, ligule, glume, lemma-palea, and in all probability, internode also.
2. Bengal—three groups (i) leaf-sheath and internode (ii) auricle, pulvinus and stigma (iii) glume and lemma-palea.
3. U.S.A.—one group leaf-sheath, internode, auricle, ligule, pulvinus and stigma.

It would appear from the above that the presence of pigment in different morphological parts occurs in different patterns or groups, which are often met with in inhertiance studies.

In considering the association between the presence of pigment in the different organs of the rice plant, the question often arises whether this association is due to close linkage or pleiotropy. Hector (1922) from his study of joint segregations of plant parts involving anthocyanin pigmentation in which one recombinant class was completely absent, concluded that a single gene in many cases was responsible for the production of pigment in several parts. Ramiah (1953a) discussing the question on the basis of data then available, considered that the genes responsible for the production of pigment in different parts of the plant remained linked. He did not, however, rule out the possibility of pleiotropy playing its parts in this association.

Recent work at the Central Rice Research Institute by Dubey (1955) and Bhattacharyya (1957) gives ample support to the pleiotropic theory for explaining

this association. Dubey studied the inheritance of anthocyanin pigmentation in the various organs of the plant in F_2 generation of 17 cross-combinations between *japonica* and *indica* varieties. He found that pleiotropy was responsible for the association of pigment in some parts, while linkage appeared to be responsible for the association of pigment in other parts. In the case of pleiotropy, one of the recombination classes is usually absent in the joint segregation. In the cross *Zuiho × Puang Nak*, leaf-sheath segregated into 45 purple :19 green, while leaf-tip-margin segregated into 27 purple : 37 green. In the joint segregation of pigmentation in these two plant parts, the following frequencies were obtained.

	Pigmented leaf-sheath and pigmented leaf-tip-margin	Pigmented leaf-sheath and green leaf-tip-margin	Green leaf sheath and pigmented leaf-tip-margin	Green leaf sheath and green leaf-tip-margin	Total
Observed	249	159	0	168	576
Expected on pleiotropy (27 :18 :0 :9)	243	162	0	171	576
	X^2	=0.159		P=0.99 to 0.98	

While there was a three-factor difference in the two parents for the segregation of pigment in the leaf-sheath and leaf-tip-margin, the mode of action of the two localization genes was different in the two organs. The production of pigment in the leaf-sheath was governed by the presence of the two basic genes A and C, and their interaction with any one or both the localization genes Lsp_1 and Lsp_2, while in the case of the leaf-tip-margin, both the localization genes and the basic genes are essential for the production of pigment. Thus in the joint segregation, the recombination class ' green leaf-sheath and pigmented tip and margin ' would not occur, showing thereby the pleiotropic effect of the genes.

Bhattacharyya studied the inheritance of pigmentation in various plant organs in eight intra *indica* cross-combinations and confirmed Dubey's findings. In the cross-combination *AC. 1225 × AC. 806*, he noted that of the total number of 32 genes responsible for the expression of pigment in 12 plant parts, four could be eliminated on account of the pleiotropy effect of certain genes. He further found, that of the genes showing pleiotropy, gene AP (purple apiculus) had the most pronounced effect as it caused the production of pigment in leaf-sheath, leaf-blade, internode and stigma. Other genes showing pleiotropic effect were LP (purple leaf blade) and Ntp (purple internode). He also found that the absence of one recombinant class from the joint segregation, was not always essential for indicating pleiotropic effect of a gene, as in the cross *D.6-24 × A.C. 806* studied by him, the pigment in leaf blade segregated into 13 green : 3 purple, while that in the apiculus segregated into 35 purple :19 green. The joint segregation was explained on the basis of the pleiotropic effect of gene Ap_2 in producing pigment in apiculus as well as the leaf blade. All the four recombinant classes were expected to be present, though in disproportionate frequencies, on this hypothesis. However, he observed one class to be completely absent and attributed this discrepancy to possible misclassification. The results of his study are given below.

	Pigmented leaf blade and pigmented apiculus	Pigmented leaf blade and green apiculus	Green leaf blade and purple apiculus	Green leaf blade and green apiculus	Total
Observed	32.0	0	134.0	93.0	259
Expected on pleiotropy (135 :9 :513 :367)	34.15	2.28	129.75	92.82	259

In the cross *Zuiho* x *Marichbeti* Dubey found that the occurrence of pigment in leaf-sheath, internode, leaf-tip and margin, glume, apiculus and stigma was governed by the same set of genes, but with varying mode of interaction in the different organs. Similar associations between certain parts of the plants were observed in other crosses as well, indicating the pleiotropic effect of gene or genes in these parts. However, there were other cases in which for the same parts, while pleiotropy was indicated for the association in some cross-combinations, close linkage appeared to be a logical explanation in other combinations. As for example, while in the cross *zuiho* x *Marichbeti* pleiotropy was found to be responsible for the association of pigment in leaf-sheath and stigma, a close linkage between the genes was indicated for the same association in the cross *Zuiho* x *Skrivimankoti.* Similar apparently contradictory results for the association of pigment in the same two parts were obtained in several other cross-combinations. Thus the problem whether the association for the presence of pigmentation between different parts of the plant is due to pleiotropy or linkage yet remains to be answered. Jodon (1955) considers that it is possible that different gene systems are responsible for the expression of anthocyanin pigmentation in different varieties. It is also probable that there is a large number of modifiers which change the expression of the same genes in different organs of the plant. The role of each gene and its inter-relationship with others, therefore, needs to be intensively studied for a proper appreciation of the genetics of anthocyanin pigmentation.

The inheritance of anthocyanin pigmentation in the various organs of the rice plant is briefly summarized below.

Root. Kadam (1938) from Bombay reported two complementary genes governing the occurrence of pigmentation in roots giving 9 coloured : 7 non-coloured. The two genes have been designated A and Rp.

Internode. F_2 segregtions of 3 : 1 and 9 : 7 of purple : green internode have been reported by Hector (1922a) from Bengal, and Mitra *et al.* (1928) from Assam ; the latter segregation was also reported by Ganguli (1942) from Assam. A trigenic ratio of 27 purple :37 green, showing the presence of three complementary genes for the expression of pigment, was also recorded by Hector (1922a) in some of his crosses. At the Central Rice Research Institute (unpublished records), the occurrence of pigment in the internode has been found to be governed by four genes (two basic genes A and C and two localisation genes Ntp_1 and Ntp_2 giving F_2 segregations of 9 :7, 27 :37, 81 :175, 117 :139 and 162 :94 of purple to green internode in various cross combinations. The ratio of 117 purple :139 green is explained on the assumption that besides the two basic genes A and C and the two localisation genes Ntp_1 and Ntp_2, there are two other genes—on an inhibitor gene Intp which in-

habits the expression of pigment and the other an anti-inhibitor gene Aintp which counteracts the effect of the inhibitor gene. The ratio of 162 purple :94 green is explained on the assumption that the presence of any one of the two localization genes with the basic genes A and C produced pigment. At the Paddy Breeding Station, Coimbatore (unpublished records quoted by Ramiah, 1953a), crosses between different types of internode-colouring resulted in a monogenic segregation of 3 self purple :1 purple lines from a cross between self purple and purple lines and a digenic ratio of 9 self purple :3 purple lines :3 light purple lines :1 green from a cross betwen self purple and green. In another cross between very dark purple lines and reddish purple lines a segregation of 12 ordinary purple lines :3 medium dark purple lines :1 very dark purple line was obtained. The above inheritance is explained by Ramiah on the hypothesis that two genes A and B, one of which is dominant over the other, control the expression of the pigment. The ordinary purple lined parent-carries both the genes, and the dark-lined parent carries neither. The hypothesis was confirmed by F_3 and F_4 observations.

Junctura. The colour in this organ varies from a few purple dots, giving a faint purple colour, to densely distributed dark purple dots, giving an almost black appearance. Complete linkage between colour in the junctura and auricle was observed by Parnell *et al.* (1917) at Madras. The same workers found the presence of colour to be simple dominant to its absence in some crosses, while in others, a digenic segregation of 9 purple :7 green was obtained by them. An F_2 segregation of 27 purple :37 green has been reported from abroad, while at the Central Rice Research Institute, Cuttack (unpublished records), F_2 ratios of 3 :1, 9 :7, 15 :1, 45 :19, 54 :10, 117 :139 and 162 :94 of purple to green have been recorded. It would therefore, appear that as in some other organs, at least two genes besides the genes A and C control the expression of pigment in the junctura. These genes may be designated as Jp_1 and Jp_2.

Junctura Back. By this term is meant the portion of the mid-rib at the junction of leaf-blade and leaf-sheath behind the junctura. While in most of the varieties the pigment in the junctura and that in the junctura back are completely associated, in certain varieties the two are independently inherited. The inheritance of pigment in this organ has been studied at the Central Rice Research Institute, and F_2 segregations of 9 :7, 27 :37, 45 :19, 54 :10, 162 :94 of purple to green obtained. The genes concerned may be designated as Jbp_1 and Jbp_2 which in the presence of the basic genes A and C produce pigment.

Auricle. Mitra *et al.* (1928) from Assam and Mahta and Dave (1931) from Madhya Pradesh have reported a monogenic segregation of 3 purple :1 green, while Hector (1922a) and Mitra and Ganguli (1932a), found colour to be conditioned by two complementary genes giving 9 purple :7 green.

Unpublished records of the Paddy Breeding Station, Coimbatore (quoted by Ramiah, 1953a) indicated that the ordinary coloured purple auricle was governed by one dominant gene, and that an additional gene made the colour darker. Dihybrid ratios of 15 :1 between purple and light purple or between light purple and green have been recorded.

PLATE I

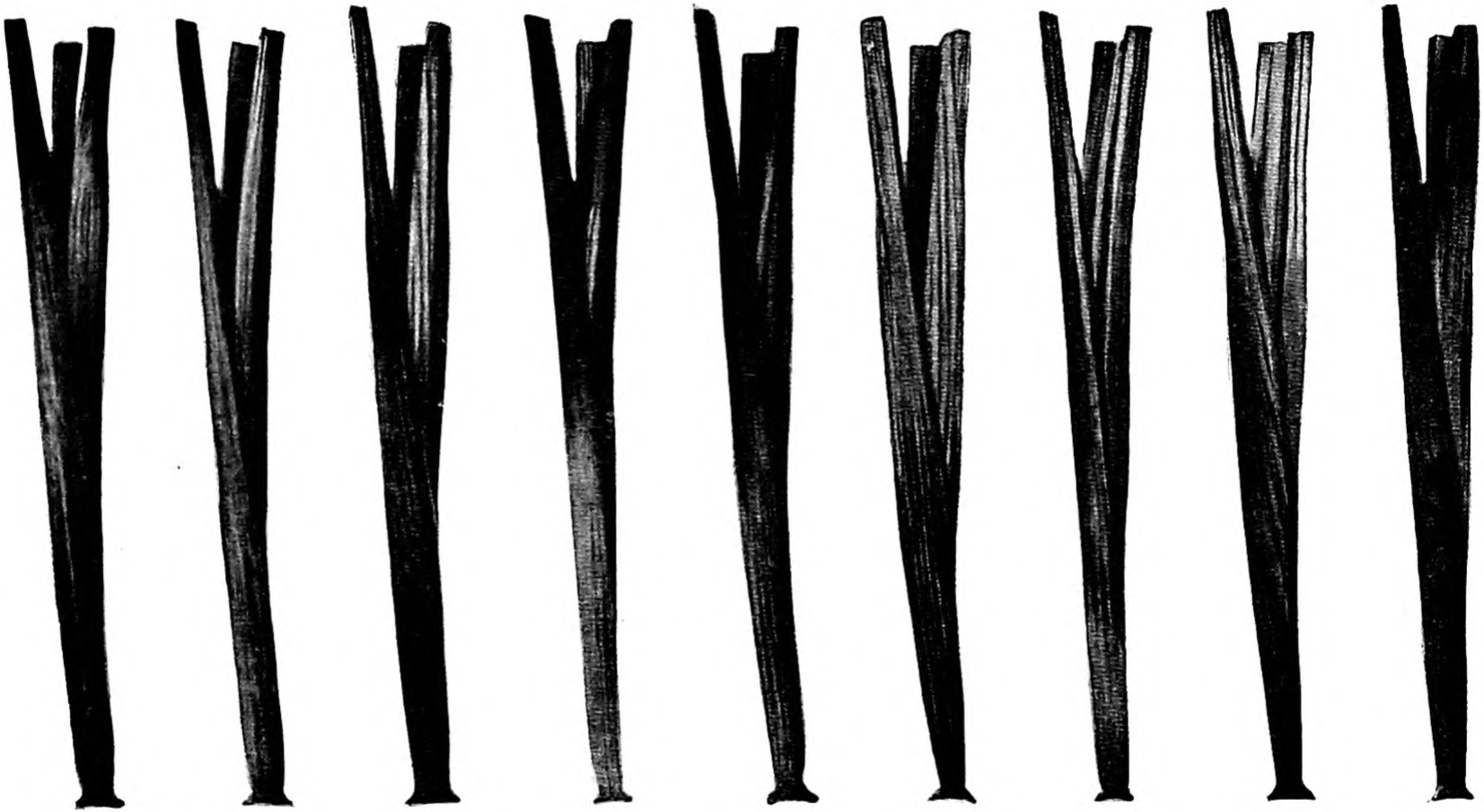
INTERNODE COLOURS

1 2 3 4 5 6 7 8

From *Rice Breeding and Genetics* by K. RAMIAH

PLATE II

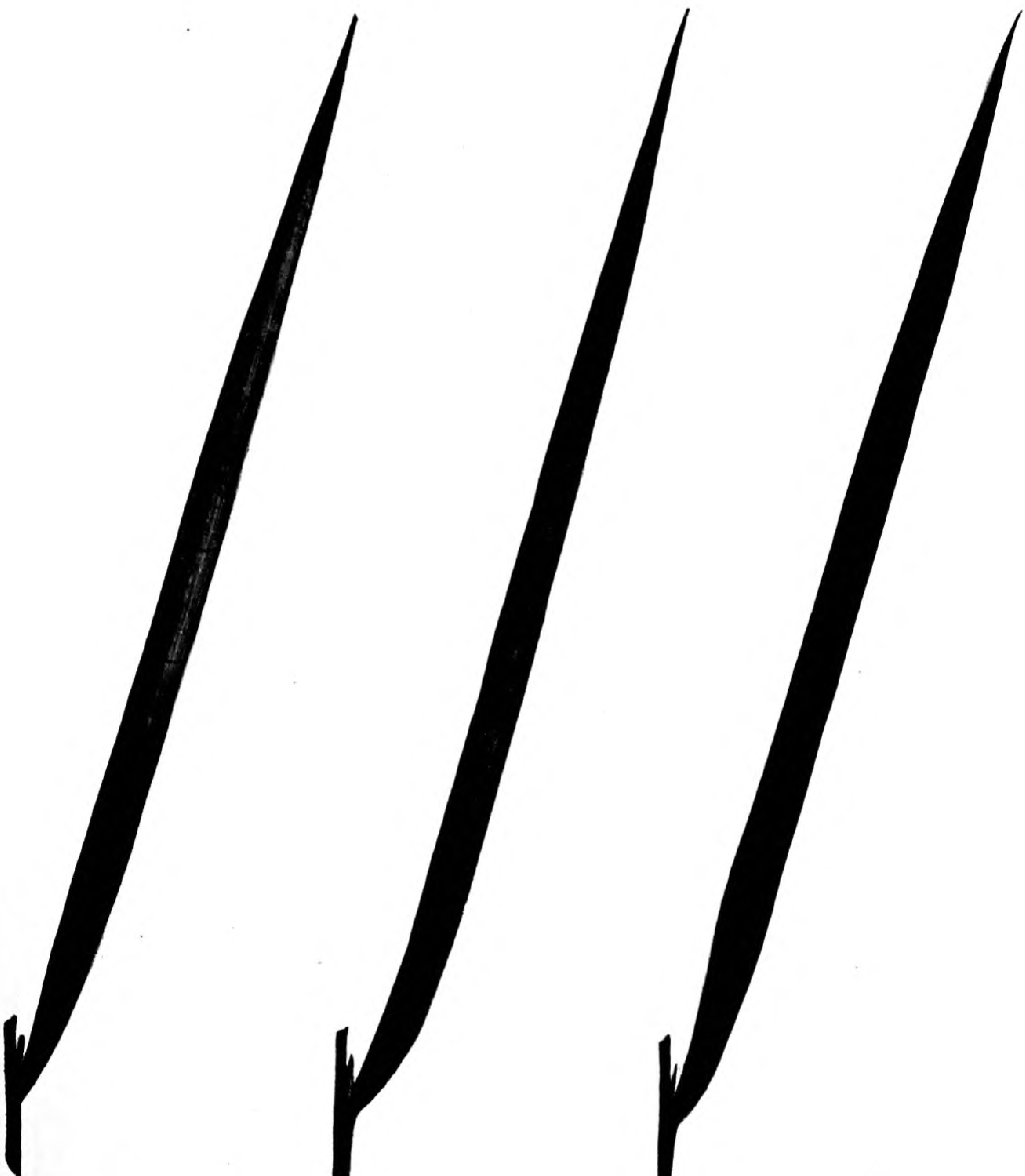
LEAF SHEATH COLOURS



1 2 3 4 5 6 7 8 9

From *Rice Breeding and Genetics* by K. Ramiah

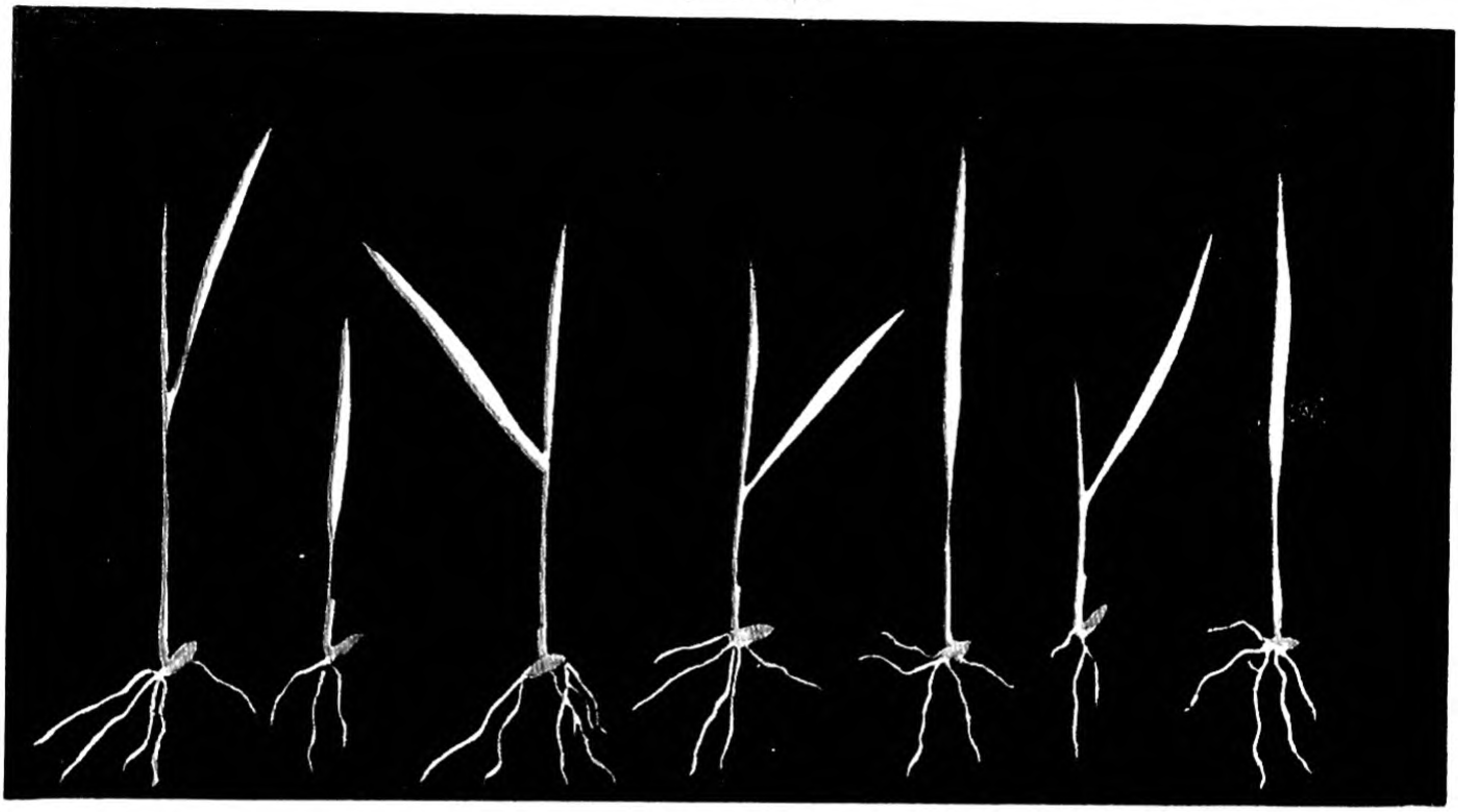
COLOUR OF LEAF BLADE



From *Rice Breeding and Genetics* by K. Ramiah

CHLOROPHYLL-DEFICIENT X-RAY MUTATIONS, COIMBATORE

[illegible] green. 2. Albino with streak or yellow in early stages. 3. Zebra-marked white. 4. Lethal yellow I. [illegible] Zebra-marked yellow-lethal. 6. Albino. 7. Lutescent. 8. Blotched. 9. Striped, not dwarf, sterile and [illegible]. 10. Green-yellow streaked. 11. Green-white striped. 12. Virescent. 13. Lethal yellow II. 14. Yellow-green striped.



1 2 3 4 5 6 7

8 10 11 12 13 14

At the Central Rice Research Institute, Cuttack (unpublished records), segregations of 3 :1, 9 :7, 54 :10 and 162 :94 of purple of green have been recorded. Thus in addition to the genes A and C, two localization genes Aup_1 and Aup_2 cause the production of pigment in the auricle with their mode of action varying in different crosses.

Ligule. The colour in the ligule varies from a few faint streaks on the sides to completely purple all over. Ramiah (1953a) has summarised the F_2 segregations recorded in crosses between purple ligule and white ligule as follows.

3 :1 of purple to white	Mitra *et al.* (1928) Mitra & Ganguli (1932a), Mahta & Dave (1931) and Ramiah (unpublished records)
15 :1 of purple to white	Ramiah (unpublished records)
9 :7 of purple to white	Hector (1922a), Mitra *et al.* (1928).
27 :37 of purple to white	Hector (1922a), Mitra *et al.* (1928)

At the Central Rice Research Institute, Cuttack (unpublished records), the colour in the ligule has been found to segregate into 3 :1, 9 :7, 54 :10, 45 :19 and 162 :94 of pigmented to non-pigmented. The various ratios are explainable on the basis of two basic genes A and C, and two localization genes Lgp_1 and Lgp_2 with varying mode of action in different crosses.

Coleoptile. Chakravarty (unpublished records quoted by Ramiah 1953a) obtained a 3:1 ratio of coloured to non-coloured coleoptile, though the fit was bad. At the Central Rice Research Institute, Cuttack (unpublished records), F_2 segregations of 9 :7, 27 :37, 54 :10, 45 :19 and 162 :94 purple to green coleoptile were obtained from different crosses. These would seem to indicate that besides the basic genes, the presence of two localization genes with varying modes of action in different cross combinations, are necessary for the expression of pigment in coleoptile. In three other crosses between pigmented and non-pigmented coleoptiles, the F_1 was green and F_2 segregated into 13 :3, 15 :1 and 229 :27 of non-pigmented to pigmented, showing the presence of one to two inhibitory genes which suppress the expression of the pigment. The pigment localization genes involved may be designated Cp_1 and Cp_2 and the inhibitory genes Icp_1 and Icp_2.

Pulvinus. The colour in the pulvinus varies from a few purple dots (thinly scattered) to dark purple dots (densely distributed) giving the pulvinus the appearance of almost a black girdle. The simple dominance of pigment in the pulvinus to its absence has been reported by Parnell *et al.* (1917), and Mitra and Ganguly (1932a) while Hector (1922a) and Mitra *et al.* (1928) have reported a 9 :7 ratio of purple to green. Ramiah (1953a) explains these two ratios on the assumption that there is a localization gene which in conjunction with the basic genes A and C produces purple colour. At the Central Rice Research Institute (unpublished records), F_2 segregations of 3 :1, 9 :7, 54 :10, 162 :94, and 243 :781 of purple to green were obtained. Thus, besides the two basic genes A and C, three more complementary genes, which may be designated Pup_1, Pup_2 and Pup_3 are concerned in the expression of pigment in the pulvinus.

Leaf-sheath. There is considerable variation in the intensity and distribution of anthocyanin pigment in the leaf-sheath. According to Ramiah (1953a) there is variation in the position of pigment, *viz.*, (i) only the parenchymatous tissue may be coloured or (ii) the vascular bundles alone may be coloured or (iii) both these may be coloured.

1. SELF-COLOUR: Hector (1916 ; 1922a) studied inheritance of leaf-sheath colour in crosses between different varieties, and has reported F_2 segregations of 3 :1, 9 :7, 15 :1, and 27 :37 of purple to green. These ratios have also been recorded by Parnell *et al.* (1917), Roy (1921) from Madhya Pradesh and Mitra *et al.* (1928). Ramiah (1953a) considers that besides the two basic genes A and C, a localization gene Lsp is necessary for the production of pigment in the leaf-sheath, and depending upon the number of genes in which the parents differ, the above ratios of 3 :1, 9 :7 and 27 :37 would be obtained. The 15 :1 segregation is caused by the duplicate genes Lsp_1 and Lsp_2.

2. PURPLE-LINE: From the unpublished records of the Paddy Breeding Station, Coimbatore, Ramiah (1953a) observed simple recessiveness of green sheath to purple-lined sheath in one cross, while in another cross between self-colour (with lines in the sheath) and green, he obtained a dihybrid segregation of 9 self-purple with lines :3 self-colour only :3 lines only :1 green. He concluded that self-colour and lines were controlled by different genes, and that the gene for purple lines was a simple dominant over green. He designated this gene as Lsv.

At the Central Rice Research Institute, Cuttack (unpublished records), leaf-sheath colour was found to segregate into 3 :1, 9 :7, 27 :37, 45 :19, 81 :175 and 162 :94 ratios of coloured sheath to green, in the various crosses between *japonica* and *indica* varieties. There thus appear to be at least four genes (including two basic genes) involved in the expression of pigment in the leaf-sheath. The two localization genes may be designated Lsp_1 and Lsp_2.

Leaf-axil. Colour in the leaf-axil is generally simple dominant to no colour, and is intimately associated with colour in the stigma. Some early workers, therefore, were led to the conclusion that the same gene was responsible for the pigment in these parts. Later studies have shown the independence of the two genes, as some crossovers have been obtained. Ramiah (1953a) is of the opinion that the two genes were closely linked. In one cross studied in Madras, however, (quoted Ramiah (*l.c.*) the dark purple axil was found to be dominant to light purple axil, and th depth of colour in the stigma was found to go with the intensity of pigment in the leaf-axil. He concluded that dark purple, light purple and green were multiple alleles.

At the Central Rice Research Institute, Cuttack, studies on the inheritance of this character in different crosses have given F_2 segregation of 3 :1, 9 :7, 27 :37, 45 :19, 54 :10, 81 :175 and 162 :94 of colour to no colour. These segregations would indicate that two localization genes, with differential mode of action in different cross-combinations, govern the expression of this character. These may be designated Lxp_1 and Lxp_2.

Leaf-blade. The F_2 segregations in blade-colour as observed by different workers in India are summarized below.

3 purple :	1 green	by Parnell *et al.* (1917)
9 purple :	7 green	by Parnell *et al.* (1917), Sethi (1934)
13 green :	3 purple	by Kadam (1936a), Dave (1938), Chakravarty (1948)
15 purple :	1 green	by Ramiah (unpublished)
3 green :	1 purple	by Dave (1938)
57 green :	7 purple	by Chakravarty (1948)

Ramiah (1953a) explains the ratios of 3 :1, 9 :7 and 27 :37 of purple to green with the help of a localization gene Lp interacting with the two basic genes A and C. The ratio of 13 green :3 purple has been shown to be due to the presence of the inhibitory factor IIp, which suppresses the production of colour governed by factor Lp in the leaf-lamina. The 57 green :7 purple segregation is explained by Chakravarty (1948) as due to the presence of two inhibitory factors which suppress the expression of colour in the lamina.

Ghose *et al.* (in press) found in the collection of genetic stocks maintained at Central Rice Research Institute, three types of fully pigmented leaf blade, e.g., purple, purple-wash and faint purple-wash. The latter originated as a mutant in the purple-wash strain. They studied the inter-relationship of the genes controlling pigmentation in these leaf-blade types. Crosses between purple leaf-blade and green leaf-blade gave an F_2 segregation of either 13 :3 or 55 :9 or 229 :27 of green to purple, showing thereby that the parents differed in 2,3 or 4 factors respectively of which one was an inhibitor gene. Purple-wash blade × green gave either a 9 :7 or 27 :37 of purple-wash to green depending upon two or three factor differences respectively, between the two parents. Faint purple-wash blade × green gave an F_2 segregation of 27 purple-wash :9 faint purple-wash :28 green. In the purple × purple-wash crosses the F_2 segregated in a trigenic ratio of 39 purple-wash :12 purple :13 green. Faint purple-wash was found to be simple recessive to purple-wash. In all cases the F_2 segregations were confirmed by F_3 results. The authors explain the above segregations on the hypothesis that A and C are the basic genes for the production of pigment. Lp and Lpw are two genes necessary for the production of purple and purple-wash pigment respectively, in the presence of A, C and the localization gene Lp. Ld is epistatic over Lpw. Ld Ld' ld are multiple alleles producing pigment in the presence of A, C, Lp or A. C, Lpw. Ld' is the mutated gene of Ld and its presence considerably dilutes the expression of the gene Lpw resulting in faint purple-wash colour. IIp is an inhibitory gene which is epistatic over Lp but does not affect Lpw. On the basis of this hypothesis the constitution of the three pigmented types of leaf blade *viz.*, purple, purple-wash and faint-purple-wash is reported to be AA CC Lp Lp lpw lpw Ld Ld ilp ilp, AA CC lp lp Lpw Lpw Ld Ld Ilp Ilp and AA CC lp lp Lpw Lpw Ld Ld' Ilp Ilp.

Some apparently peculiar segregations of leaf-blade colour have been reported by some workers. Sethi (1934) obtained an F_2 segregation of 10 green :1 purple and tried to explain on the basis of interaction of three genes. Chakravarty (1940) from Bengal has reported a ratio of 8.3 green :1 purple in one of his crosses. It

is quite possible that these two ratios are similar to 229 green :27 purple (equal to 8.48 green :1 purple) ratio obtained at the Central Rice Research Institute.

Glume. The purple glume was found to be simple dominant over green by Mitra *et al.* (1928) and Ramiah (1932), while a ratio of 9 purple to 7 green was realized by Hector (1922 a).

At the Central Rice Research Institute (unpublished records), segregations of 3 :1, 9 :7, 27 :37, 81 :175, 117 :139 and 243 :781 of purple to green have been obtained.

It would thus appear that, besides the two basic genes A and C , three complementary genes, designated as Gp_1 Gp_2, and Gp_3 are essential for the production of pigment in the glume. In certain parents in addition to the above five genes, an inhibitor gene Igp and an anti-inhibitor gene Aigp are also present.

Lemma and Palea. There is wide diversity in the distribution, intensity and location of pigment in the lemma and palea. Both lemma and palea show a similar pattern of pigmentation, and, therefore, are treated together. At ripening. the colour of the lemma-palea changes into quite a different one, and, therefore, the inheritance of pigment at flowering and at maturity are reported separately. Hutchinson and Ramiah (1938) have standardized the description of these colours.

LEMMA-PALEA AT FLOWERING : Three patterns of anthocyanin distribution in lemma-palea are recognized by Ramiah (1953a), *viz.*, (i) purple tips, (ii) purple spread, and (iii) full purple (fading slightly on ripening). According to him, when the colour extends a little lower down the apex, it is classed as 'tip and end'; when it spreads a little lower, it is termed as 'purple spread', and when the pigmentation covers the whole lemma-palea, it is called 'full purple'. The purple pigment is caused by the localization gene Hp while the purple spread and full purple are probably governed by the extension genes Hep_1 and Hep_2 respectively.

Parnell *et al.* (1917), Hector (1922a), Mitra *et al.* (1928) have shown that two complementary genes govern the expression of purple pigment in the lemma-palea. In other crosses Parnell *et al.* (*l.c.*) and Mitra *et al.* (*l.c.*) found the absence of pigment to be simple recessive to its presence.

At the Paddy Breeding Station, Coimbatore (unpublished records as quoted by Ramiah, 1953a); in one cross between two green lemma-paleas, the F_2 segregated into 9 purple spread :3 green with purple tip :4 green. He explains this on the assumption that an additional gene Hep_1 acting in conjunction with the gene for tip-colour gave the purple spread, and the absence of either resulted in green. In other cross between purple lemma and ripening gold lemma studied at the same station, the F_2 segregation was 9 purple :3 purple patchy gold :3 green straw :1 gold. The fit was bad, but the dihybrid segregation was confirmed by F_3 behaviour.

At the Central Rice Research Institute (unpublished records) F_2 segregations of 3 :1, 9 :7, 27 :37 and 162 :94 of purple to green, have been recorded for the pigmentation in lemma and palea. Thus besides the basic genes A and C, two localization genes with differential mode of action are responsible for the expresssion of pigment in the lemma and palea. These genes may be designated as Hp_1 and Hp_2.

LEMMA-PALEA AT RIPENING: A monogenic segregation of 3 dark purple: 1 tawny lemma has been reported by Ramiah (1930). The purple lemma is designated by him as Hp, while the tawny as H-t. The ripening purple is always associated with the purple lemma colour in the young stage, and therefore, the inheritance of these two characters is similar.

Apiculus. F_2 segregations of purple to green for apiculus obtained by different workers in India have been summarized by Ramiah (1953a) and are presented below:

3 : 1 reported by Parnell *et al.* (1917), Hector (1916; 1922a) and Mitra *et al.* (1928)

9 : 7 reported by Hector (1922a) and Mitra *et al.* (1928)

15 : 1 and 27 :37 reported by Hector (1922a)

Ramiah explained these ratios on the hypothesis that A and C are the two basic genes, and there is the localization gene Ap_1 which controls the expression of colour in the apiculous. A pair of duplicate genes, Ap_2 and Ap_3, was postulated to explain the 15 :1 ratio. Kadam from Bombay quoted by Jodon (1955), obtained a ratio of 171 coloured :85 colourless, and explained it on the assumption that one of the duplicate genes requires the presence of factor A alone to give colour, while the other requires both A and C to produce colour.

At the Central Rice Research Institute (unpublished records), ratios of 3 :1, 9 :7, 15 :1, 27 :37, 45 :19, 54 :10 and 162 :94 of purple to green apiculus have been obtained. These segregations can be explained on the assumption that besides the basic genes A and C, three localization genes, with varying mode of action in different crosses, are responsible for the production of pigment in the apiculus.

Awn. The colour of the awn may be white, pink or light red, brown and purple. The awn colour is mostly similar to the apiculus colour, and according to Ramiah (1953a), probably the same gene or genes control anthocyanin development in the two organs.

Sethi *et al.* (1937b) has reported a monogenic segregation of purple to white awn. At the Paddy Breeding Station, Coimbatore (unpublished records quoted by Ramiah, 1953a), a single gene difference was obtained between purple and white awns, which was confirmed by the F_3 behaviour. This gene has been designated as Anp by Ramiah (*l.c.*), who, however, considers that this gene is probably the same as the Ap_1 governing apiculus colour.

Stigma. The F_2 segregations of purple to white for stigma colour have been summarized by Ramiah (1953a), and are presented below:

3 : 1 reported by Parnell *et al.* (1922), Hector (1922a) and Mitra *et al.* (1928)

9 : 7 reported by Mitra *et al.* (1928)

27 : 37 and 81 : 175 reported by Hector (1922a)

At the Central Rice Research Institute (unpublished records), F_2 ratios of 3 : 1, 9 :7, 27 : 37, 45 : 19, 81 : 175 and 162 : 94 of purple to white have been recorded. The explanation on the occurrence of these segregations is similar to that offered for the same type of ratios occurring for pigment in other parts of the plant. Thus, besides the genes A and C, there are two localization genes, designated as Sp_1 and Sp_2, with varying mode of action which control the production of pigment.

Pericarp Colour. In the rice kernel, the colour is confined to the pericarp layer in the mature stage. The endosperm in all rices is white. Eleven kernel colours have been distinguished, the colour varying from white, which is most common, through various shades of red to purple (almost black). Such colours as gold, deep brown or grey brown also occur, though only in hybrid cultures Ramiah (1953a). The colour of rice is an important economic character. Due to its economic importance, the kernel colour has been studied by several workers and the results obtained have been summarized by Ramiah as given below.

Red × white :—3 red : 1 white reported by Hector (1913), Parnell *et al.* (1917) and Jobitharaj (1936), Paul & Mitra (unpublished)

White × White :—9 red : 7 white reported by Mitra *et al.* (1928)

Light red × light red :—9 dark red : 7 light red reported by Jobitharaj (1936) and Majid (1939)

Red × White :—15 red : 1 white reported by Ramiah and Mudaliar (1935)

Dark red × White :—12 red : 3 amber : 1 white reported by Mitra and Ganguli (1932a)

According to Ramiah, the above data show that there are complementary and duplicate genes involved in the inheritance of red rice. The interaction of two light red complementary genes, Pra and Prb, produces red colour. The two white complementary genes governing the production of dark red colour have been designated by him Pr_1 and Pr_2.

Grey-brown Rice. From a natural cross, Parnell *et al.* (1922) obtained an F_2 segregation of 9 red : 3 grey-brown : 4 white. This is explained by Ramiah (1953a), on the assumption that two pigmentation genes, A and N (N corresponds to C) , produce red rice, while the absence of A results in grey-brown rice.

Purple Pericarp Colour. Inheritance of this character has been investigated by various workers and both monogenic and digenic segregations from crosses between purple and white rices have been recorded. A 3 : 1 ratio of purple to white was reported by Parnell *et al.* (1917) from Madras and Mitra *et al.* (1932a) from Assam. Ghose and Butany (1952) from the Central Rice Research Institute, reported an F_2 segregation of 9 purple : 3 brown : 4 white and explained it on the assumption that two genes A and Prb together produced purple pericarp; Prp alone gave a brown pericarp while the absence of both resulted in white rice.

A digenic ratio of 12 purple : 3 red : 1 white was recorded by Parnell *et al.* (1917) in a cross between purple and red rice. According to Ramiah (1953a) two genes Prp and Pr are involved, purple is either Prp Pr or Prp pr, red is prp Pr and white is prp pr.

According to Parnell *et al.* (1922), an inhibitory gene **ih**, in the presence of the red gene **Pr**, produces red rice, while its absence produces golden rice. The **ih** gene in the hull inhibits the gold lemma colour and changes it to dark furrows. This gene affects the pericarp colour as well. Narasinga Rao from Madras (unpublished records quoted by Ramiah, 1953a) obtained a ratio of 9 red : 3 gold : 4 white in a cross between straw lemma with red rice and golden lemma with white

rice, thereby proving the hypothesis that in the Pr absence of the inhibitor gene, gave golden rice.

The factorial constitution of several colours in rice in terms of genes so far identified may be set down as follows, as suggested by Ramiah (1953 a).

1.	Red rice	AN Pr prp Ih	or	An Pr Prp Ih
2.	Grey rice	aN Pr prp Ih	or	an Pr prp Ih
3.	Golden rice	An Pr prp ih	or	aN Pr prp ih
4.	Purple rice	AN pr prp	or	An pr Prp
5.	Brown rice	aN pr Prp	or	an pr Prp
6.	White rice	AN pr prp	or	an pr prp

INHERITANCE OF MORPHOLOGICAL CHARACTERS

STEM CHARACTERS

The inheritance of ageotropism, tillering habit, internode characteristics and dwarfs have been investigated by workers in India.

Ageotropism. The stem of rice normally grows upright, and is, therefore, said to be negatively geotropic. Among the X-rayed material grown at the Paddy Breeding Station, Coimbatore, Madras, Ramiah and Parthasarathy (1936) obtained a plant which grew prostrate or was ageotropic. The ageotropic habit was found a simple recessive to the erect habit.

Tillering Habit. The tillers are either spreading, procumbent or compact. The compact habit has been reported by Ramiah (1930) and Dave (1939) to be simple recessive to the spreading habit. Ramiah (*l.c.*) also found compact habit to be simple recessive to the procumbent habit. The genes governing the procumbent and spreading habits have been designated Er and Es, respectively, by Ramiah (1953a). According to him, the procumbent, spreading and erect genes probably form a multiple allelomorphic series.

Floating Habit. Certain varieties growing in the flooded areas of Assam and Bengal, where the flood water may rise as much as 20 feet during the monsoon, have the capacity to grow with the gradual rise of water, and remain above the surface of water. Such varieties are called 'floating rices.' Ramiah and Ramaswamy (1941) found that the floating habit was double recessive to the normal habit, and a ratio of 15 normal: 1 floating was realised by them. The duplicate recessive genes governing the floating habit have been designated ef_1 and ef_2 by Ramiah (1953a).

Dwarfs. Parnell *et al.* (1922) studied the inheritance of the dwarf character in a cross between normal and dwarf (obtained from Burma) and found it to be simple recessive to normal. The dwarf had stiff erect stem, broad coarse leaf, and a compact stiff panicle with small grains. According to Ramiah (1953a) these characteristics were probably due to the pleiotropic effect of the dwarf gene.

Dwarfs generally originate as simple recessive mutants. Ramiah (1933b) observed some dwarfs in the F_3 progeny of one cross and some of the normals when grown, segregating into varying ratios, ranging from 2 : 1 to 6 : 1 of normal to dwarf. He thought that self-sterility was probably upsetting the ratio of 3 normal : 1 dwarf. Kadam (1937) studied crosses between normal and dwarf types from India, Japan, the U.S.A. and Australia, and suggested that there were five genes, d_1

to d_5 which were all recessive to the normal D, the gene d_2 being the most common.

At the Central Rice Research Institute, Cuttack, a dwarf mutant was located in one of the pure lines. This dwarf is characterized by a very profuse tillering habit and has been found to be simple recessive to the normal.

Dwarf mutations were induced by X-ray by Ramiah and Parthasarathy (1938) at Madras. They found that in several of these mutations, other parts of plant were also affected, showing poorly developed heads and high spikelet sterility.

Internode. At the Paddy Breeding Station, Coimbatore (unpublished records as quoted by Ramiah 1953a), the bending of the node has been found to be governed by two complementary genes, designated Nba and Nbb.

LEAF CHARACTER

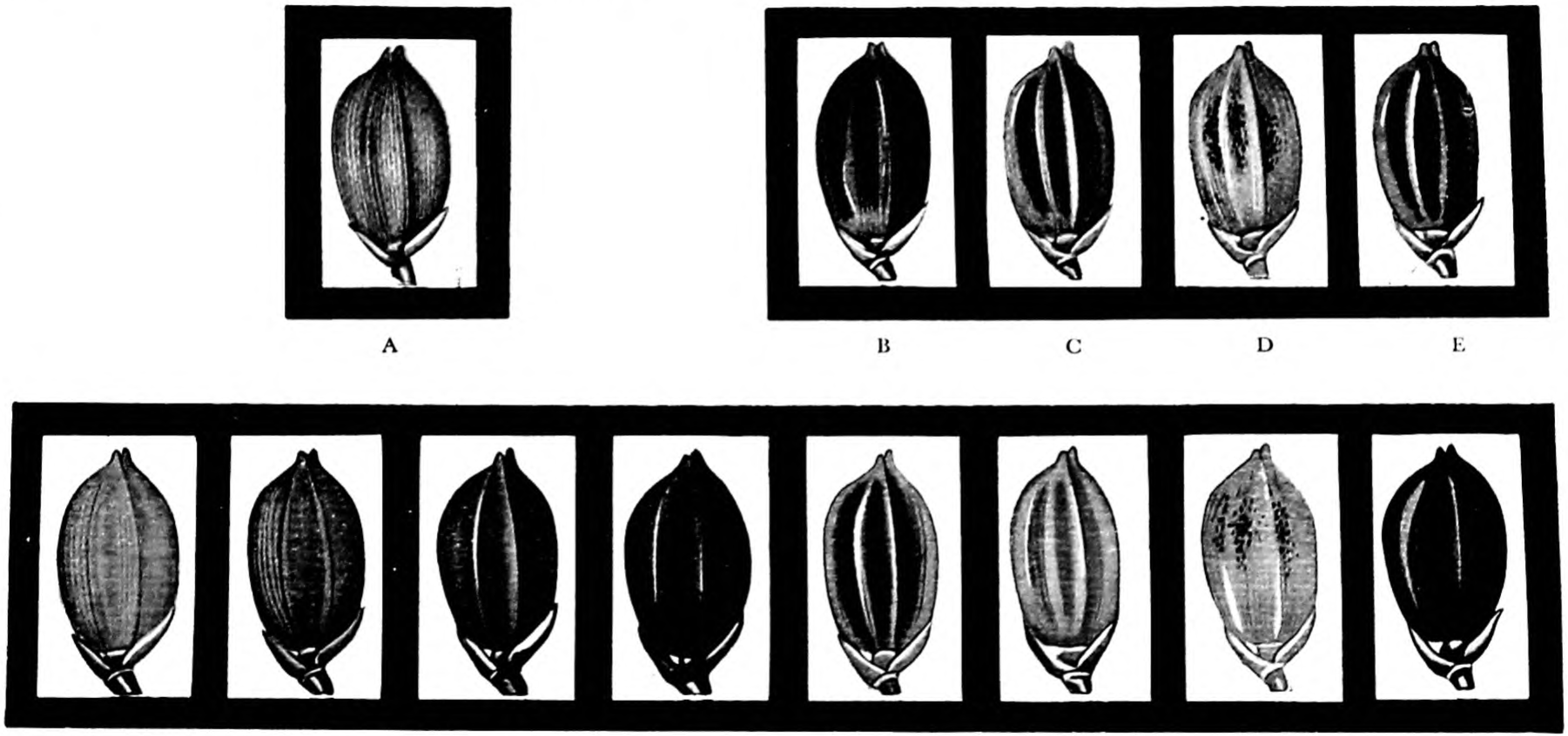
Auricle, Ligule and Junctura. A cross between an auricled and an auricle-less type was studied at Coimbatore (unpublished records quoted by Ramiah 1953a), and it was found that in the F_2 the auricle size varied considerably, ranging from normal size to no auricle, but no definite ratio could be obtained. Ghose and Butany (1952) reported the occurrence of a rudimentary auricle. This they found to be simple recessive to the full auricle. Pawar *et al.* (1954) reported a case of absence of auricle, ligule and junctura in a variety of rice and found the absence of these organs dominant over their presence. In a single segregating generation studied by them, they obtained a ratio of 8 absent : 1 present. Pawar *et al.* (1957) reaffirmed the dominance of the absence of auricle, ligule and junctura over their presence from a segregating population of a natural hybrid in the variety *Shala* studied by them, but have not reported any ratio. Ghose *et al.* (1958) isolated plants lacking auricle, ligule and junctura from the variety *Shala* studied by Pawar and his co-workers, and crossed them to a variety called *Salak* which had all these three organs present. In the F_2 a segregation of 255 present : 1 absent was obtained for each of these three organs and was confirmed by the F_3 performance. They concluded that the presence of each of these organs was governed by four duplicate genes which they have designated as Au_1, Au_2, Au_3 and Au_4 for auricle, Lg_1, Lg_2, Lg_3 and Lg_4 for ligule and J_1, J_2, J_3 and J_4 for junctura. They further found that the absence or presence of these three organs was inherited as a unit, there being no segregate in which one or more of these organs was separated. They have also reported that the genes for ligule had an additive effect with regard to its length and further that there was a positive though small correlation between ligule length and auricle length.

Bhattacharyya (1957), studied two cross combinations involving the auricle-less, liguleless and juncturaless mutant from the variety *Shala* as one of the parents. He found the presence of these three organs to be dominant over their absence and obtained F_2 ratios of 3 present : 1 absent in one combination and 45 present : 19 absent in another. The ratio of 3 present : 1 absent was confirmed by F_3 results.

Abnormalities in Size and Shape of Leaf: 1. ROLLED LEAF: A plant with rolled leaf was obtained as an X-ray mutant by Ramiah and Parthasarathy (1938) and was found by them to be double recessive to normal leaf condition. The duplicate recessive genes have been designated lro_1 and lro_2 by Ramiah (1953a).

Plate V

LEMMA AND PALEA COLOURS

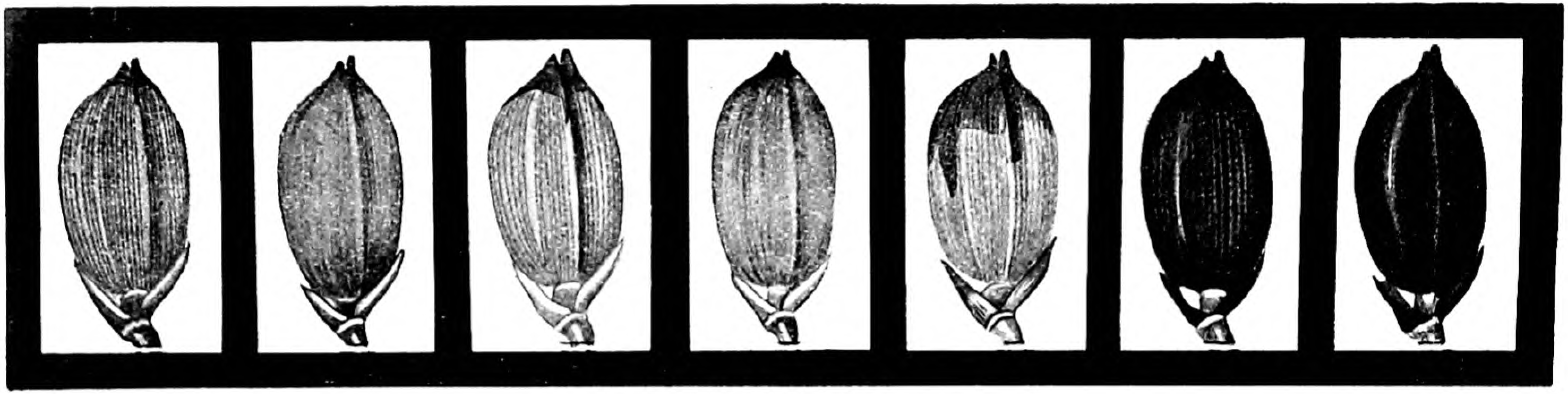


A B C D E

a-1 a-2 a-3 a-4 b c d e

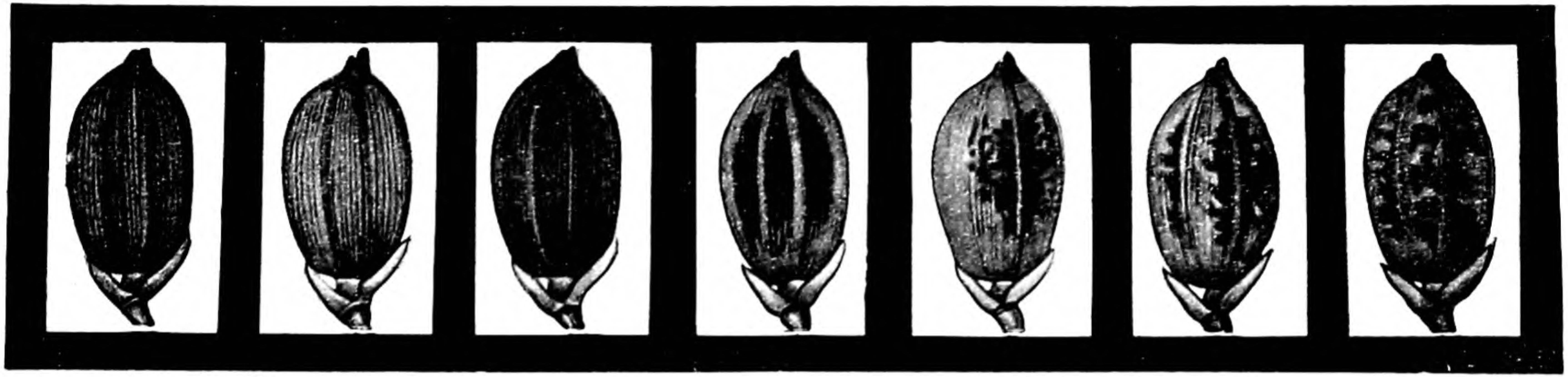
From *Rice Breeding and Genetics* by K. Ramiah

Plate V *Contd.* LEMMA AND PALEA COLOURS (*continued*)

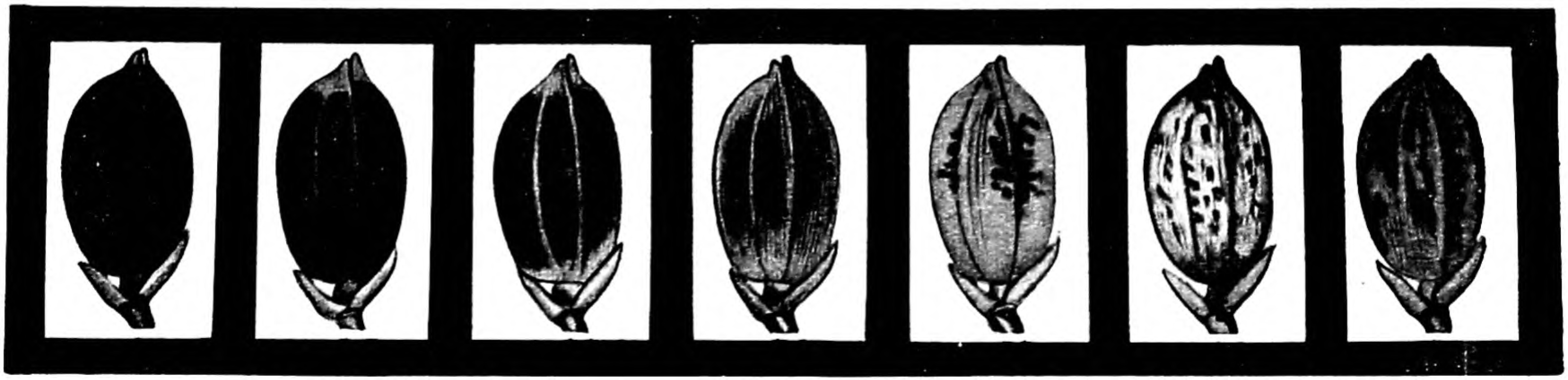


From *Rice Breeding and Genetics* by K. RAMIAH

Plate V *Contd.* LEMMA AND PALEA COLOURS (*concluded*)



M N O P Q R S

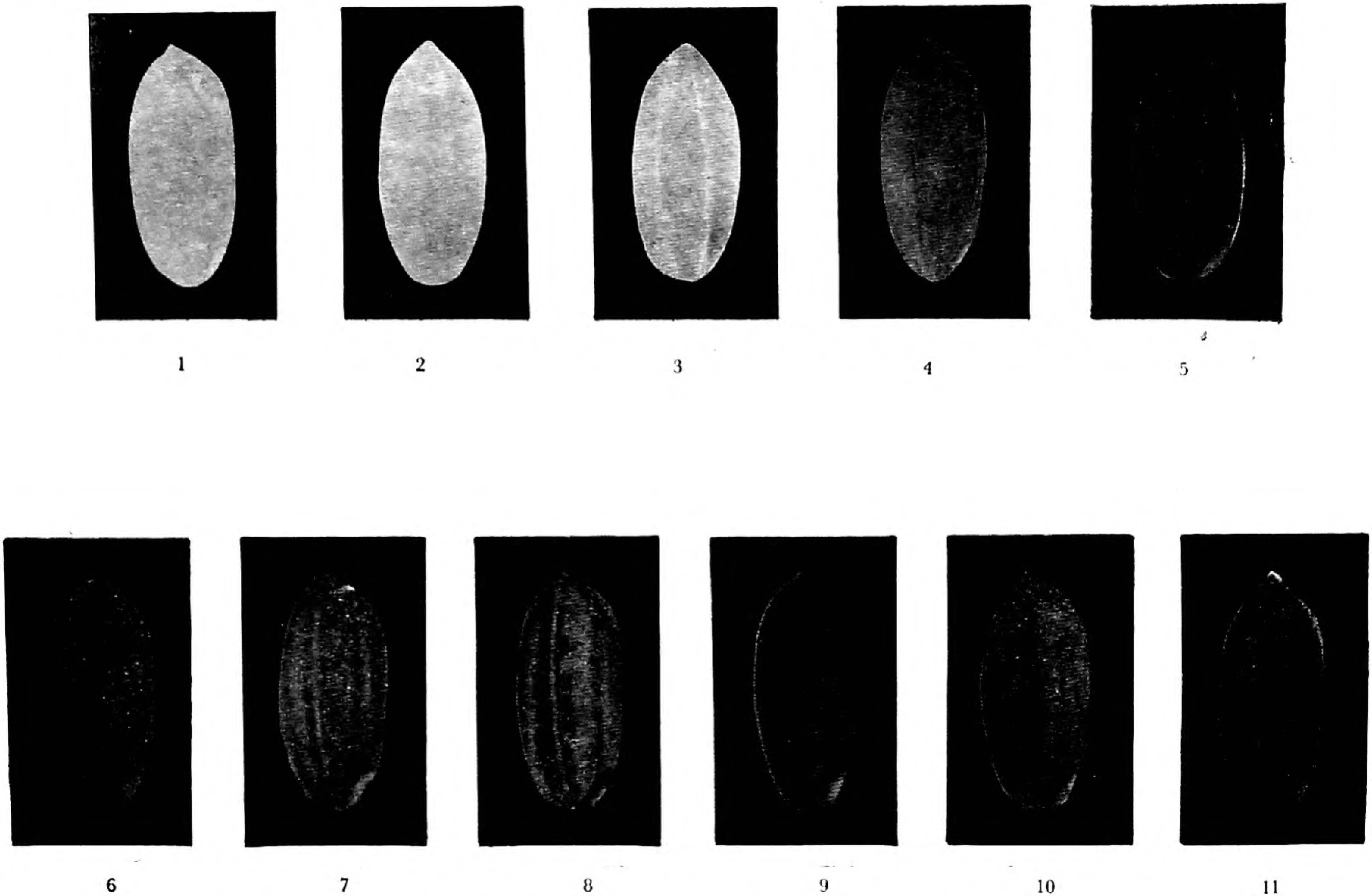


m n o p q r s

From *Rice Breeding and Genetics* by K. Ramiah

Plate VI

RICE COLOURS



From *Rice Breeding and Genetics* by K. RAMIAH

2. TWISTED PALE GREEN: Kadam (1941) observed a plant with twisted leaf which did not produce chlorophyll after the second leaf, and called it 'twisted pale green.' He found it to be simple recessive to normal leaf.

Hairiness: Hairiness was reported to be simple dominant to non-hairiness by Ramiah (1932), while Sethi (1937) found the non-hairy condition to be double recessive to hairiness, though the fit was not good. Ramiah (1953a) designated the duplicate genes controlling hairiness Lh_1 and Lh_2.

Chlorophyll Deficiencies: Hann (1933), quoted by Ramiah (1953a), has described and classified several kinds of chlorophyll deficiencies occurring in rice. Ramiah (*l.c.*), following the same terminology, has classified the chlorophyll deficiencies in rice into two groups. (i) lethals *viz.*, albino, xantha, lutescent and tip-burn yellow; (ii) non-lethals, *viz.* virescent, several types of striping on the leaf, zebra-marked and blotched. While most of the chlorophyll deficiencies follow the Mendelian laws of inheritance and are recessives, there are some which appear to be controlled by the plasm with its plastids. Chlorophyll deficiencies in rice arise mostly as mutations, either spontaneously or induced by X-ray, or by other treatments.

1. ALBINO: White seedlings called albino occur very commonly in pure-line cultures. The albino has been reported to be double recessive to green by Ramiah (1930), and Kadam and Patankar (1934). In X-ray material, Ramiah and Parthasarathy (1938) obtained both 15 : 1 and 3 : 1 ratios of normal green to albino. At the Central Rice Research Institute, the inheritance of albino has been studied in a large number of strains, and segregations of 3 : 1, 15 : 1, and 255 : 1 of green : albino have been obtained. There thus appear to be four recessive genes, which may be designated w_1 to w_4 involved in the inheritance of the character.

2. XANTHA OR LETHAL YELLOW: Such seedlings have pale yellow leaves and live for only six to twelve days after germination. Xantha was found to be simple recessive to normal green by Ramiah and Ramanujam (1935), and Ramiah and Parthasarathy (1938), while Kadam (1941) obtained both 3:1 and 15:1 of green to xantha in different materials. At the Central Rice Research Institute, Cuttack (unpublished), both 3:1 and 15:1 ratios of green to xantha have been recorded.

The genes for xantha have been designated y_1 and y_2 by Ramiah (1953a).

3. LUTESCENT: Lutescent seedlings differ from the xantha, in that they have green leaves at first, which later turn yellow, and the seedlings die away. Ramiah and Ramanujam (1935) and Ramiah and Parthasarathy (1938) obtained lutescent seedlings as spontaneous mutations in pure-line cultures. They found lutescent to be a monogenic recessive to normal green. The lutescent gene has been designated l by Ramiah (1953a).

4. TIP-BURN YELLOW: Kadam (1941) recorded an F_2 segregation of 9 green : 7 tip-burn yellow, showing the complementary nature of the genes producing this character. These genes have been designated tpa and tpb.

5. VIRESCENT: In certain varieties, there is some delay in the development of chloroplastid pigments in the seedlings, so that they appear first white or pale yellow, and then gradually turn green; the green colour usually develops from leaf-tip

downwards. These are called virescents. Ramiah (1930) has reported the virescent character to be double recessive to green. According to Kadam (1941) there are six genes governing the virescent character, five of which are non-allelomorphic and designated by him v_1 to v_5, while the sixth gene, which is an allele to v_1 and higher in the series than v_1 has been designated by him as vj_1.

6. GREEN AND WHITE-STRIPED: According to Ramiah (1953a), this is the most commonly occurring striped pattern. The first leaf is almost white with a tinge of green at the tip which later extends downwards. The second and third leaf are similar, but with more green areas, until the later-formed leaves are almost green. The striping has been recorded to be a single factor recessive to normal green by Ramiah and Ramanujam (1935). Mitra and Ganguli (1934) have reported a 12 :3 :1 segregation of green : striped : albino, and have explained it on the hypothesis that gene W which is hypostatic to gene G for green, causes the striping. Pal and Ramanujam (1941), from Delhi, have reported a peculiar type of striped pattern which was found on the leaf sheath, and which persisted in the mature plant as well as on the grains. They found this striped pattern to be simple recessive to the normal. Kadam and Ramiah (1943) designated the gene for variegated as vr.

7. ZEBRA-MARKED SEEDLINGS: The seedlings show horizontal green and yellow patches on the leaves which persist for some time after transplanting and then disappear. Ramiah and Ramanujam (1935) found this character to be monogenic recessive to normal green. Ramiah and Parthasarathy (1938) obtained similar mutations in their X-rayed material with yellow and green bands as well as white and green bands. Both these mutations were found by them to be simple recessive to green. Ramiah (1953a) designates genes zy and zw for the two types of markings. According to him, zw is epistatic to zy, and gives a 3 :1 of zw to zy. Kadam (unpublished records quoted by Ramiah, 1953a) obtained two types of zebra-marked seedlings which were found to be governed by complementary genes. These have been designated z_1 and z_2 by him.

8. BLOTCHED WHITE: Ramiah and Parthasarathy (1938) obtained a blotched white plant as an X-ray mutant. It had spots on the leaves, giving it a piebald appearance. This character was found by them to be simple recessive to normal.

Besides the chlorophyll deficiencies detailed above which follow the Mendelian inheritance, there are others on record which have been shown to follow the non-Mendelian type of inheritance. Ramiah and Ramanujam (1935) have described three cases of chlorophyll-deficiences, *viz.*, (i) green and white variegation, (ii) green and yellow variegation (yellow fading to white), and (iii) green and yellow variegation, which they have shown to be inherited through maternal plasm and plastids. Pal and Ramanujam (1941) have described a new type of variegation which, when selfed, gives rise to variegated plants and albinos in varying proportions, but when crossed reciprocally with green, gives rise to normal greens in the F_1 generation. Heterozygous green plants segregate into green and variegated in the ratio of 3 :1, with no albinos present in the progenies. Thus while variegation is a Mendelian recessive to green, albinism is transmitted maternally.

PANICLE CHARACTERS

Aberrant Panicles. Among the X-rayed material examined at Madras by Ramiah and Parthasarathy (1938), an abnormal type of plant was isolated. This had malformed, stiff panicle on which the spikelets were sparsely arranged and the floral parts were reduced. This mutant behaved as a simple recessive to normal.

Exsertion. In most rice varieties, the panicle is long exserted while in some like *Sathi* of Uttar Pradesh, the panicle does not emerge from the sheath, and the exsertion is very small. According to Ramiah (1932), exsertion of panicle is controlled by a large number of genes. Sethi *et al.* (1937a), on the other hand, observed an F_2 segregation of 49 : 3 : 12 of exserted and partly exserted : tip exserted : enclosed, and have explained their results on a three factor hypothesis with a number of assumptions.

Panicle Density. Dense panicle has been reported to behave as monogenic recessive to lax panicle by Bhide (1926) from Bombay and Ramiah (1930). Mitra and Ganguli (1932a), on the other hand, have found that density of panicle was controlled by two complementary genes giving 9 lax : 7 dense panicles. Chakravarty (1948) from West Bengal found the dense panicle to be dominant over lax panicle, and obtained a 9 :7 ratio of dense to lax. According to Bhide (*l.c.*) and Ramiah (*l.c.*), there is some association between the dense panicle and small size of grain. The gene governing the recessive dense character has been designated *lx* by Ramiah (1953a).

Clustering of Spikelets. Rice spikelets, in general, occur singly on the panicle branches, but there are a few varieties where the spikelets in the secondary branches of the panicle are clustered in groups of three to seven. The clustering habit was found to be partially dominant over normal; the F_2 segregating into 1 clustered: 2 intermediate: 1 non-clustered. Sethi (1936) reported similar results from Uttar Pradesh. The gene for clustering has been designated Cl. Kadam (unpublished records quoted by Ramiah, 1953a) obtained a trigenic segregation of 63 clustered of various degrees: 1 normal, suggesting that 3 genes govern this character.

Panicle Length. Panicle length in rice is a very variable character, and has a definite relationship with yield. Studies made by Bhide (1926) and Ramiah (1930) go to show that this character is governed by polygenes.

Glumes. The long glume found in a few varieties has been reported by Parnell *et al.* (1917) to be simple recessive to the normal short glume. However, a case of partial dominance of the short glume has been reported by Ramiah *et al.* (1931), who observed a 1 : 2 : 1 segregation of normal: intermediate: long glumes in the F_2 generation.

Awn. Awning in rice is greatly influenced by environmental factors like spacing, manuring and drought. Awns are also very variable as regards their length and distribution. In the many investigations that have been carried out, it has been shown that awnlessness is recessive to all degrees of awning. Monogenic, digenic and trigenic ratios of awned (all degrees) to awnless have been reported, as shown below.

1. *Monogenic ratio*
   3 awned : 1 awnless by Ramiah (1953a)
2. *Digenic ratio*
   9 awned : 7 awnless by Ramiah (1935)
   15 awned : 1 awnless by Alam (1931), Mitra and Ganguli (1932a) and Ramiah (1953a)
   9 awned : 6 slightly-awned : 1 awnless by Ramiah (1953a)
   12 awned : 3 partly-awned : 1 awnless by Ramiah (1953a)
3. *Trigenic ratio*
   63 awned (all classes of awning) : 1 awnless by Sethi *et al.* (1937b) and Ramiah (1953a)

At the Central Rice Research Institute (unpublished records), crosses between an awnless *japonica* variety and different awnless *indica* varieties have given F_2 segregations of awned : awnless in the ratio of 9 : 7, 27 : 37, 81 : 175 and 243 : 781. From the evidence available, awnless (irrespective of the degree of awning) would appear to be governed by five complementary genes. Two of these complementary genes have been designated by Ramiah (1953a) An_a and An_b : the remaining three genes may be designated An_c An_d and An_e. The duplicate and triplicate genes in the inheritance are designated An_1 to An_3 by Ramiah.

Multiple Pistil. Occasionally, rice varieties are found with multiple pistils, ranging from 2 to 7 in each spikelet.

Multiple pistil has been found to be simple recessive to single pistil by Parthasarathy (1935), Chakravarty (1948) and at the Central Rice Research Institute (unpublished records). Ramiah (1953a) has designated the gene for multiple pistil as mp.

Lemma and Palea. *Colour* : The different patterns of colour of lemma and palea in rice, both at flowering and ripening, have been described by Hutchinson and Ramiah (1938). The F_2 segregations recorded by different workers in India for lemma-palea colour at flowering are summarized below.

Green (straw) × Dark furrows*

3 green : 1 dark furrow reported by Parnell *et al.* (1917), Hector (1922a), Ramiah (1935), Mitra and Ganguli (1937), Dave (1938) and Majid (1939).

13 straw : 3 dark furrows by Majid (*l.c.*)

Green (straw) × Greenish (gold)**

3 green : 1 gold Parnell *et al.* (1917) and Sethi (1938)

3 yellow : 1 light brown by Mitra *et al.* (1928).

13 straw : 3 golden yellow by Alam (1936).

Dark furrows (brown furrows) × Gold (dark gold)**

3 dark furrows : 1 gold by Parnell *et al.* (1922) and Hector (1922a)

Green (straw) × Gold (dark gold)**

9 green : 3 black green : 3 light brown : 1 brown by Mitra and Ganguli (1937)

9 green : 3 black furrows : 3 patchy gold : 1 gold by Narasinga Rao (unpublished records quoted by Ramiah 1953a)

9 green (straw)* : 6 intermediate : 1 dark gold by Mitra *et al.* (1928)

Piebald pattern

9 piebald furrows : 3 dark furrows : 3 piebald gold : 1 dark gold by Parnell *et al.* (1917)

Mottling × Dirty furrows

1 dirty : 2 mottled like F_1 : 1 typically mottled by Ramiah *et al.* (1931). Thus mottling in this case is incompletely dominant.

F_3 behaviour confirmed the F_2 segregation.

Piebald × Mottled dirty

The F_1 did not show mottling clearly. 3 mottled : 1 no mottling was obtained in the F_2 by Ramiah *et al.* (1931).

Lemma and Palea colour at Ripening: The ripening colours of the lemma-palea act independently of the colour of the young stage. According to Ramiah (1953a) the same colour of the lemma-palea in the growing stage may ripen into different colours at the ripening stage, *e.g.*, a green lemma may ripen to shades of gold, brown, tawny, black or even purple. Conversely, different colours of the young stage may ripen to the same colour at maturity. The inheritance of this character is summarized below.

Ripening black (green) × Ripening straw*

3 :1 and 9 :7 ratios of ripening black : ripening straw have been reported by Parnell *et al.* (1922). However, the fit was not good.

According to Ramiah (1953a), two complementary genes designated H-b_a and H-b_b were responsible for the production of ripening black.

Ripening black (dark furrows) × Ripening straw (green)**

Mitra and Ganguli (1937) and Nandi and Ganguli (1940) obtained F_2 segregations of 36 black : 21 yellow : 7 blackish brown. They have explained their results on a three factor hypothesis. According to Ramiah (1953a), the above ratio is from a joint F_2 segregation of the lemma colour at the flowering and at ripening stage. Individually, the ratios would be 3 yellow (straw)* : 1 blackish green (dark furrows)* of lemma at flowering and 9 ripening black : 7 ripening straw lemma at ripening. Jointly, these two segregations would give 36 ripening black : 21 ripening straw : 7 ripening dark furrows.

Jobitharaj (1936) studied a cross between straw and ripening black, and obtained an F_2 ratio of 9 ripening black (green)* : 3 ripening straw (green)* : 3 ripening black (dark furrows)* : 1 ripening brown (dark furrows)*. According to Ramiah, this should represent a single factor segregation for ripening black and ripening straw, along with another single factor segregation for green and brown furrows in young stage.

Ramiah (1953a) has designated the genes responsible for various patterns of non-anthocyanin pigments of the lemma and palea. According to him, there are four genes, H^m—H^p—H^g—H^f, which form a multiple allelomorphic series, while a gene Ih inhibits gold and Ht controls distribution of gold or orange.

*Words in brackets indicate corresponding ripening colour

*The words in brackets indicate lemma-palea colour at flowering

GRAIN CHARACTERS

The size, shape, shelling characteristics, endosperm characters like texture, abdominal white and scent have been investigated by different workers in India.

Size and Shape. There is considerable variation in the size and shape of the rice grain. The size and shape of the grain is very often used as one of the distinguishing characters in classification.

Grain size is reported by some workers to be influenced by manuring and soil condition. Ramiah (1953) reports that manuring does not produce such great variations in the rice grain as it does in wheat [Engledow and Ramiah (1930)] and other cereals.

Length of Grain. The length of grain (rice in husk) varies between 5.3 mm. and 14.2 mm. Inheritance studies of this character by Parnell *et al.* (1917) showed normal length to be simple dominant over short length. Ramiah *et al.* (1931) studied a cross between the long grain (over 10 mm.) and the short round grain (5.81 mm.). The segregation obtained by this approximated to 3 short round: 1 long. This has been confirmed by Mitra and Ganguli (1938). Ramiah and Parthasarathy (1933) in one cross noted that the F_2 distribution covered the whole range of the parental limits and gave a bimodal curve. In the F_3 generation, $\frac{1}{8}$ of the total population bred pure for the grain size. They concluded that grain length in the cross under study was governed by the interaction of three factors, K_1, K_2 and K_3. They could not determine the degree to which each gene modified the length. Alam (1939) has in one cross reported a monogenic segregation of 3 short: 1 medium and a digenic ratio of 9 long : 7 short in another cross of long and short grained parents. Dave (1939) studied a number of crosses between the various grades of the rice kernel, *viz.*, very short (4.38 mm.), short (5.47 mm.), medium (6.34 mm.) and long (7.13 mm.). The results obtained by him are summarized by Ramiah (1953a) as below.

	Cross	*Segregation in F_2*
1.	Very short × short	3 short: 1 very short
2.	Very short × medium	9 short: 6 very short: 1 medium in one cross, and 3 short: 1 very short, in another
3.	Short × medium	3 medium: 1 short
4.	Medium × long	3 long: 1 medium
5.	Short × long	A long-drawn out range, the frequencies giving a normal curve.

That grain length is controlled by multiple genes has been reported by Bhide (1926), Majid (1939) and Chakravarty (1939).

Studies at the Central Rice Research Institute (unpublished records) show that length of grain is a quantitative character and is governed by three genes.

Breadth of Grain. The inheritance of the grain breadth is reported to be of polygenic character by Ramiah and Parthasarathy (1933) and Mitra and Ganguli (1938), while Majid (1939) has explained the inheritance of breadth on digenic basis. Dave (1939) found that medium grain was simple dominant over coarse grain.

Thickness. It has been observed that variation in thickness of grain among different varieties is rather small (1.5 to 2.2 mm.). This character too appears to be controlled by polygenes as reported by Majid (1939).

Shape of Grain. The shape of grain is governed by the length/breadth ratio and the length of the grain. The longer the grain, the finer it tends to be. The round shape is found generally to be dominant to the long oval shape.

Weight of Grain. The weight of the grain is of economic importance. This varies according to the size and shape of the grain. Parnell *et al.* (1922) have shown that coarse grains are heavier, and that weight is associated with grain colour.

Texture of Endosperm. The texture of the endosperm in rice is said to be hard or soft according to the amount of starch contained in it. Certain varieties of rice develop a chalky-white portion, which consists of soft starch in the middle of the kernel on the ventral side ; this is called 'abdominal white'. This character is of economic importance, as abdominal white rices have low specific gravity, contain less albuminoids, and break easily in milling and, therefore, do not find favour with rice millers.

The inheritance of this character has been reported to be roughly monogenic by Ramiah (1932), though the ratios were not definite. Jobitharaj (1936) showed that soft is partially dominant over hard, and in the F_2, a ratio of 1 soft: 2 intermediate: 1 hard was obtained. Dave (1939) records xenia effect with regard to the texture of the endosperm. He reports a segregation of 3 abdominal white: 1 translucent endosperm among the grains of the F_1 generation. According to Ramiah, the abdominal white gene may be designated Wb.

Glutinous Endosperm. Most of the rice varieties are non-glutinous, but there are some which are glutinous. In the latter, the starch deposited in the endosperm is one of the lower forms of polysaccharides (probably dextrin).

Glutinous endosperm has been reported to be a simple recessive to the non-glutinous by Parnell *et al.* (1922) and Ramiah *et al.* (1931). There is xenia of pollen on this character, as the segregation is obtained in the F_1 panicle. The pollen of the F_1 hybrid, on staining with iodine, shows two kinds of reactions, *viz.*, blue black and red, corresponding to the reaction of the endosperm of the mature kernels. The recessive gene which governs the glutinous character has been designated as wx by Ramiah (1953a).

Scent. There are certain rice varieties which give out a peculiar aroma on cooking. These are called 'scented rices', and are highly prized in Northern India. It is not known where exactly the aroma is located, as both the kernel and the husk on boiling give off aroma. The aroma also emanates from these rices when they are in flower.

Scent has been reported to be monogenic dominant to no scent by Ramiah (1937), Dave (1940) and Srinivasan (1941). A digenic segregation of approximately 9 scented: 7 non-scented has been reported by Ramiah (1937), and 15 scented: 1 non-scented by Srinivasan (1941), while a trigenic ratio of 27 scented: 37 non-scented has been reported by Kadam and Patankar (1938) from Bombay. Dave (1940) found xenia effect for this character, obtaining segregation for scent in the F_1 hybrid. Chakravarty (1948) from West Bengal has reported an F_2 segre-

gation of 13 non-scented : 3 scented, and explained it on inhibitory factor hypothesis. Ghose and Butany (1952) at the Central Rice Research Institute found non-scented to be monogenic dominant to scented. The three complementary genes have been designated O_a, O_b, and O_c, while the duplicate genes O_1 and O_2 by Ramiah (1953a).

PHYSIOLOGICAL AND QUANTITATIVE CHARACTERS

STERILITY

The problem of sterility is very important, as its presence in any form in a culture lessens the output of grain. Several forms of sterility are met with in rice. These may be classified under two groups: (i) the semi-sterile and (ii) the completely sterile.

Semi-sterile. *Spikelet Sterility*: This is the most common form of sterility met with in the semi-sterile group. In this form, varying percentages of spikelets fail to set. Apart from the genetic basis, environmental factors greatly influence the spikelet sterility in the plant. Ramiah (1931) studied sterility at Coimbatore, and observed that too much rain or too dry a condition of the soil just before flowering time increased spikelet sterility. According to Alam (1936), who studied the degree of sterility on the same plant from year to year, the age of the plant and weather conditions have no effect on the degree of sterility. In the segregating cultures, Alam found smaller frequencies for high sterility classes, and concluded that sterility might be a recessive character. Sethi (1936) observed the sterility to vary from 10 per cent. to 50 per cent. in the F_2 of crosses he was studying. According to him, the sterility character was probably controlled by multiple genes. Ramiah (1953a) suggests the basic symbol f for sterility, until more evidence is available.

Sponginess: In this form of spikelet sterility, the spikelets at the tips or base remain rudimentary and undeveloped, giving a white papery appearance. It is also called 'sterile tips' or 'white sterility'. This character has been reported to be simple recessive to normal by Ramiah (1931), who also found an association between a particular grain size and density of the panicle with sponginess. A spongy type was observed by Ramiah and Parthasarathy (1938) as an X-ray mutant, and it behaved as simple recessive to normal. It has been observed that excessive manuring may also lead to this type of sterility.

Beaked Sterile: Parthasarathy (1938b) from Madras observed three mutants in the X_3 generation which were shorter than the normal, and had beaked or curved lemma-palea. In the X_2 generation, an approximate ratio of 3 normal: 1 beaked was observed by him. The beaked sterile did not breed true in the succeeding generation, while the normals did. Cytological examination by him revealed it to be trisomic of a primary type.

Another type of mutant observed by Parthasarathy (*l.c.*) in the X_2 generation was shorter in stature, had thicker and fewer culms with close arrangements of spikelets in the panicle and with about 25 per cent. sterility. This was called a stumpy mutant, and was found to be a trisomic (2n+1) of the secondary type.

Completely Sterile. Under the completely sterile class, a number of types, such as paleaceous sterile, barren sterile, male sterile and female sterile, have been reported.

Srinivasan (1938) at Madras obtained a plant in which the inflorescence and spikelets resembled the multi-pistillate type. It was called 'paleaceous sterile' and was completely sterile.

A mutant plant, which was characterized by lateness, with thin and long flag leaf and small earheads with reduced flowers, was obtained by Ramiah (1936) in Madras in the X-rayed material of a pure line. It was called 'barren sterile'. He found this character to be governed by duplicate recessive genes, which he has designated fb_1 and fb_2. Anandan and Krishnaswamy (1934) from Madras observed a barren sterile mutant in a pure line of *Muthu samba*, which was characterized by dimorphism of the grain size in the plant heterozygous for the barren sterile condition. The character was found to be simple recessive to normal. Ramanujam and Parthasarathy (1935) found a sterile plant in a pure line, in which the flowers did not open normally and the anthers were reduced and non-dehiscent. This mutant was due to the non-pairing of the homologous chromosomes (asynapsis). The asynaptic condition segregated in the ratio of 9 normal : 7 asynaptic plants, showing that two complementary genes designated by Ramiah (1953a) fas_a and fas_b were concerned in the production of asynaptic mutants.

Total Male Sterility: A male sterile plant obtained in the variety *GEB. 24* by Ramanujam (1935) at Madras was found to be simple recessive to the normal. The monogenic segregation of this character has been confirmed by Srinivasan (1938).

DURATION

Rice varieties vary in their duration (*i.e.*, the period taken from sowing to maturity) from 80 days to over 200 days. The varieties can be classed as (i) period-bound, and (ii) season-bound. The period-bound types take more or less the same number of days to complete their life-cycle, irrespective of the season in which they are sown, while the season-bound varieties come to flower only at a certain season of the year, irrespective of the time of sowing. Mitra (1924) reported from Assam that the *aus* rices were period-bound, while the *sali* varieties were season-bound. Ramiah (1933a) planted a medium-duration variety all the year round in Coimbatore, and found that the period of maturity varied from 90 to 230 days, depending on the time of planting. According to Sethi *et al.* (1936a), the flowering duration was more affected in short duration transplanted rices than in late types, delayed planting resulting in precocious flowering. The response of rice varieties belonging to *aus* and *aman* groups to different sowing dates was studied by Chakravarty (1938) in Bengal. He found that *aus* varieties took more or less the same period to flower except for the plantings done in November and December. In *aman* varieties, except for the October-November plantings, the varieties flowered at about the same time.

Short duration was found to be simple dominant to long duration by Ramiah (1933a), Hector (1922b) and Bhide (1926). The last-mentioned author observed the segregation to be very near to 3:1 of earliness to lateness. Ramiah also noted a shift for duration in the extracted pure early and pure late types, which were found to be later than the early parent and earlier than the late parent, respectively. In another cross where the parents differed in duration, the F_1 was found by Ramiah

(*l.c.*) to be on the early side and the F_2 covered the range of the two parents. In F_4 some selections gave 3 early : 1 late. The extracted early types were later than the early parent by 14 days, and the extracted late types were 18 days later than the late parent. He explained the results on the assumption that two genes designated by him as E_2 and E_3 with cumulative effect controlled earliness, one of these genes being present in each parent.

In another cross between two parents of nearly similar duration (96 and 89 days), Ramiah (1933a) found the F_1 to be earlier than the parents, and in the F_2 transgressive variation on either side of the two parents was observed. This indicated the presence of multiple genes for duration. In the F_3 of some other crosses, a segregation of 3 early : 1 late was noted in some families, while a ratio of 1 early : 3 late was observed in others. An inhibitory factor was suggested by Ramiah as responsible for the latter segregation. He confirmed his hypothesis by test crosses.

A segregation of 15 early : 1 late was noted by Ramiah (1933a) in a cross in which the two parents differed in duration by about five weeks. He has tried to explain this segregation on the trigenic basis, assuming a differential effect for the three genes.

Studying crosses for duration in Uttar Pradesh, Sethi *et al.* (1936b) found lateness to be simple dominant over earliness in one cross, the F_3 behaviour confirming their F_2 observation. In another cross, Sethi *et al.* (1938) found the F_2 distribution to be continuous and transgressive, and concluded that the inheritance of duration was governed by multiple genes.

Nandi and Ganguli (1941a) studied a number of crosses between summer, autumn and winter rices in Assam. In one cross between an early summer and winter rice, they obtained a bimodal distribution, giving a ratio of 3 early : 1 late on either side of the minimum frequency class. In another cross between an early summer and autumn rice, the F_2 gave a one-sided transgressive segregation, there being no plants earlier than the early parent, but having plants which were later than the late parent. There was a break, and the frequency on either side gave a ratio of 3 late : 1 early. In the third cross between an autumn and winter rice, they observed a transgressive distribution on either side, and a ratio of 3 late : 1 early was obtained. They have explained their results on the basis of three genes. According to Ramiah (1953a), the above inheritance could be explained on a digenic basis as was done by him (Ramiah, 1933a) for the results obtained at Coimbatore.

Chakravarty (1938), as quoted by Ramiah (1953a), studied a cross between a short duration (*aus*) variety and a long duration (*aman*) variety. The F_1 was intermediate, and the F_2 was grown on different dates. The first set was broadcast on May 15, while the second and third sets were transplanted on July 20 and 31, respectively. The segregation in the first set was 3 late : 1 early, while that in the second and third sets was continuous and normal. Srinivasan (1937) from Madras has recorded the dominance of period-bound habit over the season-bound one.

From the evidence available, Ramiah (1953a) concludes that the inheritance of duration may be simple in some cases, and more complicated in others. According to Chandraratna (1955) the sensitivity to the photoperiod is determined by a single dominant gene Se. He contends that in the previous investigations on the inheritance of duration, the relationship between anthesis and photoperiod was not taken into consideration. He thinks that the segregation of 3 late: 1 early noted by some investigators possibly resulted from the expression of genes at the Se locus, when the F_2 received long days, while the unimodal (polygenic) distribution might have been obtained in instances where either the two parents were both day-neutral or the F_2 was subjected to day-lengths approximating the optimum.

HEIGHT

This is an important character of plants. Too great a height, which results in lodging at an early stage, is a disadvantage, and too short a growth, even with a good yield, is not generally preferred by the Indian cultivators, who value the straw as fodder for the livestock. An optimum height resulting in a fair harvest of grain and straw is desirable. There is a great variation in height, and the mean height in over 3,000 genetic stocks maintained at Cuttack varies from 46.2 cm. to 221 cm. Height is greatly affected by environmental conditions. From the investigations carried out by Ramiah (1933b), it would appear that height is a quantitative character. However, some cases of monogenic segregation with tallness as dominant have also been reported by Ramiah (*l.c.*) and Nandi and Ganguli (1941b). In one case, the last two authors found tallness to be recessive. Results of some other investigations have been explained on the basis of two to three genes, designated T_1, T_2, T_3 by Ramiah (1953a), each gene having differential effects, as controlling height.

Height shows positive correlation with exsertion, length of ear and yield. Association between height and duration showed that shortness went with earliness, and tallness with long duration.

TILLERING

This is an important varietal characteristic, and is subject to considerable variation due to environmental conditions like manuring and spacing, and on account of this not much progress has been made in the study of inheritance of this character. Several tillering studies, have, however, been analysed on the assumption that environment has had a uniform action on all the plants.

Tillering has been shown to be a polygenic character by Bhide (1926) and Ramiah (1953a) (quoting unpublished records from Coimbatore). From the evidence available Ramiah (*l.c.*) concludes that genes numbering three to four in some cases, and more than four in others, control tillering.

LODGING OF STRAW

Considerable loss in yield is caused by lodging, the amount of damage done to the crop varying with the stage of the plant at which lodging takes place. According to Pillai (1955), a maximum loss in yield occurs when the crop lodges just before flowering, or immediately after it. Various morphological characters in relation to the lodging habit have been studied by some workers in India, but no definite or clear relationship has been established. Bhide (1926) and Ramiah and

Mudaliar (1934) have reported the inheritance of these characters to be monogenic with lodging, as dominant over non-lodging. The gene pair governing this character has been designated Ld—ld by Ramiah (1953a). In the crosses under study, the non-lodging habit was found associated with poor tillering and longer duration. Bhide (*l.c.*) observed that besides poor tillering, the erect flag leaf was associated with non-lodging.

GRAIN SHATTERING

Shedding or shattering of grain at the time of harvest is another character which causes loss in yield in rice. There are considerable differences in the amount of shattering in the rice varieties, and even by a rough examination at the time of harvest, the cultivated rices may be classified into groups with varying amounts of shattering. It has been seen that generally varieties with a round shape of grain show more shattering than varieties with long or oval shape of grain. The ripening black character of lemma-palea also shows some association with shattering.

In the inheritance studies that have been carried out, shattering has been reported to be simple dominant to non-shattering by Ramiah (1934). Bhalerao (1930) from Bombay found shattering to be dominant over non-shattering, but considered that more than one gene were involved in the inheritance of this character. Kadam (1936b) showed that duplicate genes governed shattering, and these have been designated Sh_1 and Sh_2 by Ramiah (1953a).

Ramiah and Hanumantha Rao (1936) have studied this character quantitatively. They found the F_1 intermediate, and got a high coefficient of variation in the F_2, but did not find the segregation transgressive. They carried their investigation to F_4. They found positive coefficient of correlation between F_2 and F_3, and F_3 and F_4 . In F_4 all families with high degree of shattering bred true, while only some of the families with intermediate shattering segregated. They could not come to definite conclusions about the genic nature of shattering. According to Ramiah (1953a), while the above inheritance was not simple, many genes were not involved in the expression of this character.

Sethi (1933) noted the shattering character to be partially dominant over non-shattering, but thought that more than one gene was involved in its inheritance.

FLOOD-RESISTANCE

There are certain areas where flooding or inundation of the land occurs for varying depths and periods. Owing to the difficulties of studying varieties grown under flood our knowledge of flood-resistance is meagre and, genetic studies are yet to be undertaken. Growth studies have shown that (1) the seedlings which are somewhat older by the time the floods occur, show a greater resistance to submersion, (2) the initial height of the seedlings is no index of their capacity to resist flood submersion and (3) yield and flood resistance are not correlated, and a rapid growth is not necessarily accompanied by high yield.

DROUGHT-RESISTANCE

Ramiah (1953a) observes that inheritance studies on resistance to drought have not been reported in India, but it is common observation that certain varieties grown under restricted condition of water supply thrive better than others. This

would show that capacity to resist drought is genotypic, and is governed by specific genes in the varieties concerned.

It has been observed that *O. longistaminata* (*O. perennis*) is able to withstand drought conditions better than the cultivated rice. Srinivasan *et al.* (1941) were able to isolate drought-resistant forms from crosses between cultivated rice and the wild rice *O. longistaminata* (*O. perennis*).

RESISTANCE TO SALINITY

Inheritance studies on resistance to salinity have not been reported, but as some varieties are able to tolerate a greater percentage of salinity than others, it is probable that this character is controlled by a specific gene or genes (Ramiah 1953a).

SEED-DORMANCY

Dormancy or after ripening of the grain is generally characteristic of the medium and long duration rice varieties, while it is usually absent in the short duration ones.

The causes of dormancy in rice are not clearly understood. However, it is generally thought that the husk of the grain is in some way responsible for the dormancy. Since its removal brings about normal germination as reported by Parija and Chalam (1940) and Chalam and Behera (1956) or considerably improves germination as observed by Narayanan and Lakshmanan (1951) and Butany and Gangadharan (in press). According to Chalam and Behera (*l.c.*), the spikelets of dormant varieties absorb less than 30 per cent. of water by weight, which is the minimum amount necessary for germination. Butany and Gangadharan (*l.c.*) on the other hand did not find any relationship between the quantity of water absorbed by a variety and its dormancy.

There is a considerable variation in the period of dormancy of different varieties. According to Chalam (1954) this period was proportional to the flowering duration of a variety, but Chalam and Behera (1956) reported that the period of dormancy extended up to 30 days. Mudaliar and Sundararaj (1954) found that the period of dormancy varied between 3 to 13 weeks, while Butany and Gangadharan (*l.c.*) observed that the period of dormancy was a varietal character and is not always related to the duration.

Among the methods successfully used for breaking seed dormancy in rice, are smoking of soaked seed with wet straw or coconut coir by Parija and Chalam (1940), centrifuging of soaked seed of variety *T. 812* at 1,500 rpm for 10 minutes reported by Samantrai and Dubey (1953), and treating seeds with N/10 sulphuric acid for 3 hours found by Butany and Gangadharan (*l.c.*) who also found that treatment of seed with mercuric chloride (1 :1,000) improved germination of both hulled and unhulled seeds.

Inheritance of seed dormancy in rice has been studied by Shanmuga Sundaram (1953), who reported the presence of more than one gene in the inheritance of this character. Besides, the main genes, certain modifiers are reported to be present.

RESISTANCE TO BLAST DISEASE

The inheritance of resistance to Blast disease was studied by Ramiah and Ramaswamy (1936) at Coimbatore, in two crosses *Korangusamba* × *GEB 24.* and

Korangusamba × *CO. 4* the two male parents being less susceptible to *Piricularia* than *Korangusamba*, a high-yielding and popular variety susceptible to Blast. In the first cross, it was considered that resistance might be a simple recessive to susceptibility, while in the other cross it was found to be more complicated. From Japan, Sasaki (1922) as quoted by Ramiah (1953a) reported simple dominance of immunity over susceptibility, while Nakatomi (1926) quoted by Ramiah (*l.c.*) found the resistance to *Piricularia* to be controlled by two complementary genes. The two genes are designated Pi_a and Pi_b.

LINKAGE RELATIONSHIPS

There are twelve pairs of chromosomes in rice, and, therefore, only twelve linkage groups are possible. A good deal of work has been done in the genic analysis of several characters, but the actual assignment of these genes to the various linkage groups is still in the initial stage. Most of the knowledge on linkage is based on studies of F_2 segregation ; the back-cross method of determining linkage has not been used due to lack of a rapid method of producing a large number of hybrid seeds.

In India, studies on linkage have mostly been carried out by workers in Madras State. Ramiah (1953a) has summarized the results of linkage studies in India as presented below. The gene symbols used are, as far as possible, those recommended by Kadam and Ramiah (1943).

Linkage	Reported By
1. Between genes $H\text{-}b_a$ and Hb_b for ripening black colour of hull and Ntv for purple lining of internode with 16.8 per cent. crossing over.	Parnell *et al.* (1917)
2. Between genes Lgp (coloured ligule) and H-p (coloured hull) with 12.5 per cent. crossing over.	Hector (1922a)
3. Between genes wx (glutinous) and one of the complementary genes Ap for anthocyanin pigment in lemma-palea and apiculus, with 29.0 per cent. crossing over.	Ramiah *et al.* (1931)
4. Between genes fs (spikelet sterility) and fl (flowering duration) and Ex (ear exsertion); no crossing over per cent. given.	Ramiah (1931)
5. Between genes Lxp (leaf-axil coloured purple) and fs (spikelet sterility) (no crossing over per cent. given.	Ramiah (1931)
6. Between genes Kr for small round shape of grain and An_1 and An_2 for awning with 13.6 and 24.1 per cent. crossing over, respectively.	Anandan (1933) from Madras

7. Between genes T (plant height) and fl (flowering duration); No crossing over per cent. given.	Ramiah (1933c)
8. Between genes for hg (gold lemma-palea) and Fl (long duration) and between hg and T (tall plants); no crossing over per cent. given.	Ramiah (1933c)
9. Between genes mp (multiple pistils) and fs (spikelet sterility) ; crossing over per cent. not given.	Parthasarathy (1935)
10. Between genes Prp (pericarp colour) and one of the complementary genes Oa or Ob (for scent in the grain) with 14.7 per cent. crossing over.	Ramiah (1937)
11. Between genes fi (flowering duration) and of (floating habit) with 30.0 per cent. crossing over.	Ramiah and Ramaswamy (1941)
12. Between genes Ap (apiculus colour) and Sc. (dominant clustering of spikelets). No crossing over value given.	Parthasarathy (unpublished records) quoted by Ramiah (1953a)
13. Between genes Ap (purple apiculus) and H^{pb}-H^{f} (lemma-palea colours at flowering) and between Ap and H-b (lemma-palea colour at ripening) with 28.7 per cent. and 27.3 per cent. crossing over, respectively.	(Unpublished records) quoted by Ramiah (1953a)
14. Between genes Ntp (purple internode) and Prp (purple pericarp) and between genes Ap (purple apiculus) and au, lg, j (lack of auricle ligule and junctura) with a cross over value of 5.06 and 29.66 per cent. respectively.	Bhattacharyya (1957)
15. Between genes Ap (purple apiculus) and Gp (purple glume) and between Gp and Aup, between Ap and Aup with 1.2, 8.46, and 7.6 per cent. crossing over, respectively.	Unpublished records of the Central Rice Research Institute.

Studies carried out by Ramiah (1935) are considered by Ramiah (1953a) to indicate that several genes controlling the development of anthocyanin pigment of different organs of the plant could be fitted into the three linkage groups shown below. Two of these groups are based on the study of two crosses, *viz.*, *T.102* × *T.29* and *T.102* × *T.6.*

GROUP I—PIGMENT PRESENT IN

Lsv-leaf-sheath lines.
Ntp-internode

Lxp-leaf-axil
Jpl, one of the duplicate genes for junctura
Aup_1-one of the duplicate genes for auricles
Lgp_1-one of the duplicate genes for ligule
Sp-one gene for stigma
Hp_1-one gene for lemma
Ap_1-one gene for apiculus

GROUP II—PIGMENT PRESENT IN

Lsp-leaf-sheath(without lines)
Jp_2-one of the duplicate genes for junctura
Aup_2-one of the duplicate genes for auricle
Lgp_2-one of the duplicate genes for ligule

The third group is based on the linkage of glutinous endosperm wx with other characters.

GROUP III

Ap_2-a gene for purple apiculus
wx-gene for glutinous endosperm
cl-gene for clustered spikelet
Hf-gene for dirty brown furrows in lemma
H-ba or *B-bb*-one of the genes for ripening black colour in lemma.

Ramiah (1953a) also reported that further studies had shown that a gene for purple septum and a gene for purple ripening colour of lemma also belonged to the group I mentioned above.

Jodon (1948) reviewed the linkage data available then, and tentatively placed the genes into eight linkage groups. Nagao (1951), formed four linkage groups from the data of the Japanese workers and suggested re-modification of Jodon's groupings. Jodon (1955-56) taking into consideration Nagao's groupings and linkage data from India presented by Ramiah (1953a) revised his 1948 linkage groupings and observed that placing of some of the genes involving anthocyanin pigmentation cannot be done with certainty in Group II and Group III due to lack of sufficient data.

CHAPTER 12

CYTOLOGY

Botanical research on rice in India has included the cytological studies on the cultivated types, chromosome variants, wild species and interspecific hybrids.

The somatic chromosome number in all the cultivated types of rice examined has been found to be twenty four. The chromosomes are small, the size ranging from *circa* 0.6 micron to 3 microns, and a precise study of the karyotype has proved difficult. Nandi (1936) found that there was a gradation in size from the largest to the smallest chromosome, ten types could be distinguished, and two small chromosomes were duplicated. He was able to identify two pairs of satellited chromosomes differing slightly in their length. Sethi (1937) compared the mitotic chromosomes of different varieties. He found that the somatic complement could be classified into five large, four medium and three small pairs. Phatak (1940) found that four pairs of chromosomes had median constrictions, the rest having sub-median and sub-terminal primary constrictions. Parthasarathy (1938a) confirmed the observations of Kuwada (1910) that somatic pairing of chromosomes was present in rice. He found clear evidence of pairing only in some preparations, and even in the favourable preparations, the maximum number of pairs was only ten.

There are differences between varieties in the number of nucleoli formed at the mitotic telophase. Usually, either two or four nucleoli are formed. Since the maximum number of nucleoli in mitosis is four, it is inferred that two pairs of satellited chromosomes are likely to be present in the karyotype, though a direct confirmation has proved difficult. Ramanujam (1938) found that the number of nucleolar bodies formed initially is under genotypic control and that four could be the original number of nucleolar bodies in rice.

The meiosis in *O. sativa* is normal, and 12 bivalents are formed regularly. The chiasmata are mostly terminal at the metaphase, and two to three bivalents are held together loosely at this stage. A secondary association of bivalents is present in the meiotic metaphase. The maximum association observed by Nandi (1936) was two groups of three bivalents and three groups of two bivalents. He also found occasional quadrivalents along with normal bivalents.

The somatic chromosome number in the species of *Oryza* uptil now has been found to be either 24 or 48, and the 24-chromosomed *O.sativa* is usually considered as a diploid. Nandi (1936) has advanced the theory that the genus *Oryza* originated by polyploidy, and that *O.sativa* is a secondary polyploid. He postulates that the ancestral species had the basic chromosome number of five, and that the basic chromosome number 12 of the genus *Oryza* arose by hybridization, duplication of two chromosomes and polyploidy. One evidence supporting this theory is the duplicate and polymeric genes identified in rice. The cytological evidence supporting this theory has already been cited. These are the shapes and sizes of chromosomes, and the formation of four nucleolar bodies at the telophase. The polyploid origin of the genus could give rise to a secondary association of bivalents, occasional

quadrivalent formation in a diploid, and pairing of chromosomes in a haploid, and these configurations have been observed.

Cytology of wild species of *Oryza* has interested Indian workers. Ramanujam (1937b) reported that the somatic chromosomes of *O.officinalis* were larger in size than those of the cultivated species *O.sativa.* Nandi (1938) studied meiosis in *O.minuta* and found normal bivalent formation in this tetraploid species and concluded that this species was amphidiploid in origin.

Cytological investigation in progress at the Central Rice Research Institute, by Sampath and co-workers, has shown that besides *O.officinalis,* the mitotic chromosomes are larger than those of *O.sativa, O.australiensis* and *O.granulata* while they are smaller in *O.perennis* and *O.brachyantha.* With regard to chromosomes pairing in the tetraploid species, 3-4 quadrivalents per cell were observed in O.*alta* and *O.latifolia.* In *O.ridleyi* the frequency was found to be nil to two per cell. In this species, anaphase irregularities, laggards and bridges were also found to occur. In *O.eichingeri,* Shama Rao and Seetharaman (1955) reported quadrivalents up to a maximum of five per cell.

The following cytological features which are parallel to those found in *O.sativa* were observed in some wild species. One pair of satellited chromosomes was found in *O.officinalis, O.granulata* and *O.ridleyi.* Somatic pairing as in *O.sativa* was found in *O.officinalis* and secondary association of bivalents were seen in *O.officinalis* and *O.australiensis.*

Crossing of the wild species among themselves and with *O.sativa* has been attempted, and cytology of some of the species hybrids has been studied in India. For the purpose of interpreting the data on interspecific hybrids, the genus *Oryza* may be tentatively divided into three following sections, on the basis of the distribution of the species and the morphological and anatomical studies carried out at the Central Rice Research Institute by Shah (1955): (1) Section Sativa includes the species *O.sativa, O.perennis, O glaberrima, O.breviligulata,* and *O.australiensis*; (2) Section Officinalis, includes *O.officinalis, O. minuta, O. eichengeri, O. latifolia,* and *O. alta*; (3) Section Granulata includes *O. granulta, O.ridleyi, O. coarctata* and *O. brachyantha.*

Numerical variation in the chromosomes of *O. sativa* has been found to occur rarely in nature and has been produced artificially also. Haploids have been isolated from hybrid progenies. Ramiah *et al.* (1934) found a haploid amongst the twin plants isolated from the variety, *GEB.24.* They found that this variety gave twin seedlings with a low frequency, and that from such twins occasional haploids could be obtained. The height and spikelet size of the haploids were reduced, and it was sterile. However, the haploid produced a small number of well-developed pollen grains, and when it was pollinated from a diploid, a few seeds could be obtained. In the meiotic division in the haploid the association of some chromosomes in pairs was observed. At the Central Rice Research Institute a haploid was found in an F_3 population of a *japonica-indica* cross. This plant was completely sterile and the size of the panicle and height of the plant were considerably reduced. At meiosis ten chromosomes were found unpaired and the remaining two showed loose pairing. From this plant diploid sectors were obtained by repeated vegetative propagation and also by colchicine treatment.

Naturally occurring autotriploids have been found occasionally (Ramiah *et al.* 1933), and their origin has been explained on the assumption of the union of an unreduced gamete with a normal one. However, artificial production of autotriploids has not been successful. At the Central Rice Research Institute, extensive crossing of tetraploids and diploids was undertaken for this purpose, but no success was obtained. Triploids show good vegetative growth, increased spikelet size and are sterile. Ramanujam (1937a) studied meiosis in an autotriploid, and found 10 trivalents to be frequently formed. He also found one instance of hexavalent pairing. The segregation in A.I. stage was irregular, and most of the pollen formed aborted. The percentage of normal pollen was found to vary with the season. He found that by allowing cross-fertilization with diploid plants some seeds set in the triploid, and these seeds gave diploids and anueploids. A naturally occurring triploid in a population of *T. 1242*, an improved rice variety of Orissa, was studied at Central Rice Research Institute by Karibasappa (1957). He observed in this triploid at meiosis, a mean frequency of 9.4 trivalents per cell. The pollen fertility was found to be 39 per cent. and spikelet fertility below one per cent. even under conditions of open pollination. The germination of seeds of this triploid was poor and most of the seedlings failed to survive. However, from the progeny three anueploids with somatic chromosome numbers 26, 26, and 27, respectively, were obtained.

Allotriploids have been produced artificially by crossing a tetraploid species with cultivated rice. Rice crosses freely with the tetraploid *O. eichingeri*, and the hybrid is completely sterile. There is no seed-setting even on back-crossing to either parent (Central Rice Research Institute—unpublished records). Nandi (1938) crossed *O. sativa*, with the tetraploid *O. minuta*, and this hybrid was also sterile. Ramanujam (1937b) secured sterile allotriploid by hybridization *O. sativa* and *O. Officinalis*. In this study, the F_1 of *O. sativa* and *O. officinalis* was 24-chromosomed, and when this was back crossed to *O. sativa* a 36-chromosomed plant was obtained. Shama Rao and Seetharaman (1955) secured a sterile allotriploid by crossing *O. glaberrima* and *O. eichingeri.*

Tetraploids have been found to occur naturally, and have also been produced artificially by colchicine treatment of seedlings (Ghosh, 1950 ; Cua, 1950 and 1952 ; Siregar, 1952 and Sampath, 1952). The tetraploids show an increased size of the vegetative parts as also of spikelets. A semi-sterility is present in all the tetraploids studied in India, and the factors controlling semi-sterility are under study at the Central Rice Research Institute. Two types of tetraploids can be produced artificially, the homozygous types from a pure strain, and hybrid tetraploids from crossed seeds. A comparative study of homozygous and hybrid tetraploids was carried out by Matai (1955) at the Central Rice Research Institute. He found that there was a general increase in cell dimensions as a result of teraploidy. The photoperiod response of homozygous tetraploids was not markedly different from that of the corresponding diploids. Tetraploidy affected some physiological characters like water absorption of germinating seeds, water-content of seedlings, and nitrogen-content of seeds. Sampath and Seshu (1957) confirmed that the protein content in tetraploids was higher than in the diploids.

Comparative study of some diploids and of the tetraploids derived from them, carried out at Central Rice Research Institute (unpublished records) has shown that though the grain size is increased by tetraploidy, plant yield is reduced due to semi-sterility and reduction in the number of ear-bearing tillers. In another investigation it was observed that manuring of tetraploids increased their fertility. In a study of meiosis in hybrid and homozygous tetraploids the mean number of quadrivalents per cell was found to be seven in the former and eight in the latter. However, the hybrid tetraploids were not more fertile than the homozygous ones.

Anueploid of 24+X types have been produced by Ramanujam (1937a) by allowing a triploid to be cross-pollinated by diploids. He found that the vegetative growth and flowering were markedly affected in plants having a somatic chromosome number of more than twenty-five. One instance of anueploid rice with chromosome number less than twenty-four was reported by Sampath and Krishnaswamy (1948). They found a naturally occurring variant with 23 somatic chromosomes and the progeny of this anueploid segregated for 24, 23 and 22 chromosomed plants.

Structural variation in the chromosomes of rice is both of theoretical and practical interest. From the prevalence of semi-sterility in the hybrids between *iaponica* and *indica* varieties of rice, it has been inferred that the sub-species formation in rice is connected with structural changes in the chromosomes, in addition to gene mutations (Terao and Midusima 1939 and Cua 1952). However, visible differences between the chromosomes of *indica* and *japonica* varieties have not been found. Sampath and Mohanty (1954) observed a low frequency of chromosome 'bridges' and fragments in the A.I. stage of meiosis in *japonica-indica* hybrids and concluded that inversions of chromosome segments have played a part in the formation of the *japonica* sub-species, Venkataswamy (1957) isolated a true breeding semi-sterile culture from F_6 of a *japonica-indica* hybrid in which one or two quadrivalents were frequently present in M.I. stage of meiosis. He concluded that translocation of chromosome segments may also have contributed to the formation of *japonica* sub-species. Structural changes in rice chromosomes have been produced by X-ray treatment. Parthasarathy (1938b) observed structural changes of the chromosomes as well as gene mutations in progenies of X-ray-treated rice. Chromosomal variations observed in the progenies included segmental interchange, primary and tertiary trisomy.

The four species of the section Granulata have been neither inter-crossed, nor crossed with any species from the other sections. In the section Officinalis, two intra-sectional hybrids have been recorded. Nandi (1938) has studied the hybrids *O.officinalis* × *O.minuta* and found that the genom of *O.officinalis* is present in the tetraploid *O.minuta*. Morinaga (1943) studied the hybrid *O.minuta* × *O. latifolia*, and observed some pairing of chromosomes, with a maximum of 12 bivalents per cell at meiosis suggesting that one genom was common to the two tetraploid species. Interspecific crosses with the species of the section Sativa and the fertility of hybrids are shown in Table 17. The first seven hybrids in the Table are from intra-sectional crosses and the next five from inter-sectional crosses.

TABLE 17. INTERSPECIFIC CROSSES WITH SPECIES OF SECTION *Sativa* AND THE FERTILITY OF THE HYBRIDS

Sl. No.	Species Crossed	Hybrid Fertility	Reference
1.	*O.sativa* × *O.perennis* (Orissa type)	Semi-sterile	Central Rice Research Institute (unpublished)
2.	*O.sativa* × *O.perennis* var *cubensis*	Sterile	Jones and Longley, 1941
3.	*O.sativa* × *O.perennis* var *longistaminata*	Largely sterile	Srinivasan, 1941
4.	*O.sativa* × *O.glaberrima*	Semi-sterile	Central Rice Research Institute (unpublished)
5.	*O.sativa* × *O.breviligulata*	Semi-sterile	Central Rice Research Institute (unpublished)
6.	*O.glaberrima* × *O.perennis* (Orissa type)	Semi-sterile	Central Rice Research Institute (unpublished)
7.	*O.glaberrima* × *O.bereviligulata*	Semi-sterile	Central Rice Research Institute (unpublished)
8.	*O.sativa* × *O.officinalis*	Sterile	Ramanujam, 1937*b*
9.	*O.sativa* × *O.eichingeri*	Sterile	Central Rice Research Institute (unpublished)
10.	*O.sativa* × *O.minuta*	Sterile	Nandi, 1938 and Morinaga, 1940
11.	*O.glaberrima* × *O.eichingeri*	Sterile	Shama Rao and Seetharaman, 1955
12.	(*O.sativa* × *O.officinalis*) F_1 × *O. eichingeri*	Sterile	Srinivasan *et al.* 1941

Meiosis has been studied in hybrids 1,4,5,8,10, and 11. The hybrids 1, 4 and 5 are between species of the same section, and in these normal pairing with the formation of 12 bivalents was observed. In hybrid 8 an inter-sectional cross, there was complete failure of pairing. In hybrid 10, between *O. sativa* and *O. minuta*, Nandi (1938) observed bivalent formation up to a maximum of twelve, but, this observation could not be confirmed by Morinaga (1940). In hybrid 11, also an inter-sectional cross, Shama Rao and Seetharaman (1955) observed a combination of auto and allosyndesis of chromosomes in the meiotic division.

These data support the grouping of species into sections. Further work on the cytology of interspecific crosses is in progress.

CHAPTER 13

PHYSIOLOGY

NUTRIENT UPTAKE AND PLANT GROWTH

Extensive fertilizer trials have been conducted in India to determine the manurial needs of the rice crop under different soil, climatic and cultivation conditions. Along with this, fundamental studies on the growth and nutrient uptake have also been pursued.

Sahasrabuddhe (1928) estimated that the rice crop, on an average, removed 28 lb. of nitrogen, 20 lb. of P_2O_5, 60 lb. of K_2O and 28 lb. of CaO per acre. Workers in Bombay (Anon. 1953) have further reported on the uptake of nutrients by the rice plant. They observed that (1) the greatest uptake of the nutrients—nitrogen, phosphate and potash—takes place between the 14th and the 70th day after transplanting, and there is no uptake of these nutrients after the flowering starts ; (2) there is an indication of the flow back of these nutrients after flowering ; (3) lime continues to be absorbed up to maturity; and (4) the uptake of silica increases from flowering to maturity. From these observations, they concluded that it may not be necessary to apply fertilizers to the soil at or after the flowering stage.

Studies on the growth and uptake of nutrients by the rice crop have also been reported by Desai (1955) from Hyderabad. He studied a long duration variety, and observed that the greatest increase in dry matter, nitrogen and potassium occurred during the reproductive stage, and that nearly 66 per cent. of the total was accounted for during this period. The absorption of phosphate, however, showed no such rapid increase, and only about 28 per cent. of the total was absorbed during the reproductive phase. He further reported that the phosphate accumulated in the vegetative tissue was sufficient to enable the plant to complete its life-cycle, even if there was a shortage of phosphate in the soil at the flowering stage. Nitrogen supply was, however, considered essential at the flowering stage and if this became critical at that period, the plant suffered, and the yield was brought down considerably.

The growth and nutrient uptake by rice varieties of different durations (*Ptb.10* and *Mtu.15*, short duration ; *T.141*, medium duration and *BAM.9*, long duration) have been examined under field conditions at Central Rice Research Institute, Cuttack (unpublished records), during the main crop season, June to December. Short duration varieties were also examined during the second crop season, December to April. All varieties received a basal manurial application of 30 lb.N, 30 lb. P_2O_5 and 30 lb. K_2O per acre. It was found that the active tillering phase of all varieties started about 10 to 12 days after transplanting and maximum tillering stage was attained about four to five weeks after transplanting irrespective of duration of the variety. After the maximum tillering phase was reached, reduction in the number of tillers occurred in all varieties due to death of late and ill-developed tillers. In short duration varieties, ear initiation followed almost immediately after the maximum tillering stage, while in the medium and late duration varieties,

there was a time lag between maximum tillering and ear initiation, the interval being more with longer duration varieties. Results are in general conformity with observations made by Ramiah and Narasingham (1936) and Ramiah (1953a).

Regarding uptake of nitrogen by different duration varieties, it was seen that the short duration varieties differed from the medium and long duration varieties. In the short duration varieties, nitrogen uptake was vigorous till flowering after which it slowed down ; the uptake from planting to maturity followd almost a sigmoid curve. With medium and long duration varieties, however, nitrogen uptake, reached its first maximum with attainment of maximum tillering stage, and then slowed down till ear initiation stage was reached, after which the nitrogen uptake was again vigorous, reaching its second maximum with the completion of flowering. Later, after flowering, there was a decline in the nitrogen content of medium and long duration varieties.

Role of nitrogen, phosphate and potash in rice production has been examined by a number of research workers in our country. Nitrogen particularly has received the most attention because of its importance in the growth of the crop, almost on all soil conditions in the country. A deficiency of this nutrient leads to stunted growth, poor tillering, pale yellow green leaves, small earheads and low yield of grain. An excess of this nutrient has also been found harmful, resulting in poor yield of grain and production of more straw. Krishnamoorthy (1955) frcm Hyderabad has reported critical limits for nitrogen in leaf for successful crop growth. Third leaf from the top of the plant, when the panicles had half emerged, was analysed and critical levels of nitrogen in the leaf found as follows.

(1) *Lowest critical content*	1.4 per cent. N or less.
(2) *Normal content*	2.0 to 2.5 per cent. N.
(3) *Luxury consumption*	3.0 per cent. N or greater.

Dastur and his associates (1933-40) from Bombay conducted extensive water culture and field studies on the growth and uptake of nitrogen by the rice plant. They determined the relative efficiency of ammoniacal and nitrate fertilizers for rice culture. Dastur and Malkani (1933) reported that the absorption of NH_4-N decreased and that of NO_3-N increased as the plant aged, and that a mixture of $(NH_2)_3 SO_4$ and KNO_3 was a better source of nitrogen to the rice plant than either of these used singly, at the same total nitrogen level was present in the mixture. Dastur and Pirzada (1933), working on the same problem confirmed that the mixture of ammonium and nitrate fertilizers was better than either of the two used alone. They also reported that the manuring of the crop should be done as early as possible after planting, or even earlier at transplanting, as late manuring had very little effect on the growth and yield of the crop. Dastur and Kalyani (1934) observed that during the early stages of growth, the proteins of the cells of the plant tissues were on the alkaline side of the iso-electric point, and, therefore, they combined readily with basic ions than with acidic ions, and hence the basic ammoniacal nitrogen ions were preferred to the acidic nitrate ions. During the later stages of the growth of the plant, the proteins of the cells were on the acidic side of the iso-electric point, and, therefore, they combined more readily with the negatively charged ions, leading to decreased absorption of ammonium

ions and increased absorption of nitrate ions. The comparative efficiency of ammonium and nitrate nitrogen for rice crop has also been examined recently at Central Rice Research Institute, Cuttack (unpublished records) under solution culture technique. It was observed that under moderate supply of nitrogen (20 ppm), there was not much difference between ammonia or nitrate as source of nitrogen supply (100 ppm.), however, the highest grain yield was obtained only when ammonium nitrogen was given at early stages of growth and nitrate nitrogen later at reproductive stage. Ammonium nitrogen, at higher levels, given to plant at reproductive stage was definitely harmful, retarded growth and reduced yield of crop considerably.

Field experiments on the use of ammonium and nitrate fertilizers for rice crop were conducted by Dastur (1940). In these trials a mixture of ammonium sulphate and sodium nitrate was found superior in six, inferior in five and equal in twelve experiments to ammonium sulphate used alone. Soil culture studies in parts have been recently conducted at Central Rice Research Institute (unpublished records) to evaluate the efficiency of ammonium and nitrate ion on yield and nitrate uptake by plant. It was seen that with full dose of nitrogen applied as basal application, about 50 to 60 per cent. of the nitrogen in the fertilizer was taken up by the crop with ammonium sulphate and only about 10 to 15 per cent. with sodium nitrate. The yield response with single application of nitrate fertilizer was about one-third of that obtained with purely ammonium fertilizer. With split application of nitrogen, two-third applied basal as ammonium sulphate and one-third top dressed just prior to ear initiation either as ammonium sulphate or sodium nitrate, about 75 per cent. of topdressed nitrogen was taken up with ammonium sulphate and only about 30 to 35 per cent. with sodium nitrate. There was, however, no difference in grain yield, whether the topdressed nitrogen was applied in the ammonium or nitrate form, but straw yield with topdressed ammonium nitrogen was significantly higher.

The superiority of a mixture of ammonium and nitrate nitrogen over sulphate of ammonia alone as a fertilizer for rice under water-logged soil conditions has therefore, not been established. In trials conducted at the experimental stations, ammonium sulphate, and ammonium fertilizer, has invariably proved more efficient than a nitrate fertilizer, and a mixture of the two forms is seen to have intermediate fertility value depending on the relative proportion of ammonium and nitrate form of nitrogen in the fertilizer. The reason for this is that in rice soils under flooded condition, leaching and denitrification processes in the reduced sub-surface zone of the soil denitrify a considerable part of the applied nitrate nitrogen (Abichandani and Patnaik, in presss), and render it ineffective as a fertilizer for crop growth.

Investigations on the nitrogen uptake by the rice plant and its influence on the growth and yield of rice were conducted at the Central Rice Research Institute in water culture experiments during the second crop season with short duration *indica* and *japonica* rices. The *japonica* variety gave a higher response to nitrogen than the *indica* variety. The maximum yield from *indica* was obtained at 20 ppm, of nitrogen, while that from *japonica* at 60 ppm. of nitrogen. The yield and growth data observed are given in Table 18 and 19 (Central Rice Research Institute—unpublished records).

TABLE 18. PERFORMANCE OF *indica* AND *japonica* VARIETIES AT DIFFERENT NITROGEN LEVELS

Nitrogen ppm.	*Indica*	..	*PTB.10*	*Japonica*	..	*Aikoku*
	Grain gm/pot	Straw gm/pot	% N in grain	Grain gm/pot	Straw gm/pot	% N in grain
0	5.0	8.2	1.04	1.5	7.1	1.30
5	24	23	1.30	19	20	1.33
20	64	51	1.65	45	33	1.42
60	61	77	1.98	73	61	1.53
150	49	92	2.16	70	68	1.87

TABLE 19. GROWTH CHARACTERS OF *indica* AND *japonica* VARIETIES UNDER GRADED LEVELS OF NITROGEN

Nitrogen ppm.	*Indica*	..	*PTB.10*	*Japonica*	..	*Aikoku*
	Top length cm.	Root length cm.	Ear No. per pot	Top length cm.	Root length cm.	Ear No. per pot
0	81	56	8	49	41	4
5	93	51	18	60	33	23
20	114	46	38	70	31	42
60	109	26	54	73	28	60
150	107	23	54	73	27	62

The differential behaviour of *indica* and *japonica* rices is clearly marked. While *indica* yielded better than *japonica* at low fertility levels of 0, 5 and 20 ppm. N, the *japonica* gave more yield at higher nitrogen levels. This difference between the two varieties has been found to be due to their capacity to assimilate absorbed nitrogen. The *indica* variety is not able to utilize nitrogen as efficiently as the *japonica* variety at high fertility levels of nitrogen. The former variety under these conditions accumulates comparatively more soluble nitrogen in the plant body at the reproductive stage, resulting in production of more straw and reduction in yield of grain. Ratio of soluble to protein nitrogen for the two varieties at vegetative and reproductive stages respectively is shown in Table 20.

TABLE 20. RATIO OF SOLUBLE TO PROTEIN X 100 FOR *indica* AND *japonica* VARIETIES

Nitrogen level ppm.	Vegetative Stage *Indica Ptb 10*	*Japonica Aikoku.*	Reproductive stage *Indica*	Reproductive stage *Japonica Aikoku*
0	25	20	27	26
5	31	31	34	33
20	41	38	34	32
60	39	36	43	35
150	47	47	55	45

It was seen that while at the vegetative stage, there was no difference in the ratio of soluble to protein nitrogen between the two varieties, at reproductive stage *indica* had a higher ratio at 60 and 150 ppm. N. This showed that the nitrogen metabolism of *indica* was disturbed at higher fertility levels as assimilation of nitrogen by plant was not able to keep pace with nitrogen uptake.

Effect of nitrogen level on growth and ear emergence is reported by Misra and Samantrai (1955a) from sand culture trials. They found that increasing nitrogen levels had no effect or near emergence, but produced luxuriant growth by augmentation of tillers. Higher nitrogen levels also promoted the maintenance of green colour of leaves and elongation of stem axis.

Tanaka *et al.* (1958) from Central Rice Research Institute, Cuttack, have studied the influence of increasing levels of nitrogen from 0 to 200 ppm. N on growth characters of an *indica* variety (*Ptb. 10*) under solution culture technique. They observed four distinct stages of nitrogen utilization by plant. First is the deficiency stage from 0 to 10 ppm. N where both grain yield and nitrogen content in the grain increases with increase in nitrogen supply; the second is the normal stage from 20 to 40 ppm. N where grain yield increases with nitrogen supply, but there is no sharp increase in the nitrogen content of the grain. The nitrogen level for optimum grain yield lies in the range 30 to 40 ppm. Third is the luxury stage from 40 to 60 ppm. N where the nitrogen content of the grain increases with increase in nitrogen supply, but there is no appreciable difference in yield of grain and straw. Fourth is the excess stage from 60 to 200 ppm. N where growth of the crop is retarded and grain yield decreases with increase in nitrogen supply, although nitrogen content of both grain and straw continue to increase.

The time of nitrogen application with respect to 'partial efficiency' of nitrogen absorbed at different stages of plant growth, for production of grain has also been examined at Central Rice Research Institute, Cuttack (unpublished records) under solution culture technique. 'Partial efficiency' of nitrogen has been defined by Kimura and Chiba quoted by Mitsui (1955) as increase in yield of grain or straw obtained with unit increase in nitrogen uptake by the plant. This was taken as a criterion of effective use of nitrogen absorbed by the plant. It was seen that

with a medium duration *indica* variety, *T.141*, grown at low level of nitrogen supply (10 ppm.), two stages of maximum 'partial efficiency' were obtained; one at active vegetative growth period and the second at flowering. The results indicated that rice plant grown at low nitrogen supply needed an additional dose of nitrogen before flowering stage to push up crop yield. At high nitrogen supply (60 ppm.) how ever, the nitrogen taken up by the plant up to maximum tillering stage was found sufficient for later growth and additional dose before flowering was not necessary.

Increased nitrogen absorption at different stages of growth, at low nitrogen supply affected the growth and yield of grain as follows.

1. Increased nitrogen absorption up to ear initiation stage increased tillering capacity of the plant.

2. Increased nitrogen absorption for ear initiation to flowering stage and increased the number of grains per panicle.

3. Increased nitrogen absorption from flowering to maturity increased the weight of grain.

Investigations on the mineral nutrition of the rice plant have been carried out by Sircar and his associates at Calcutta. Sircar and Sen (1941) reported on the phosphorus nutrition of the rice plant from a series of sand culture trials. They found that phosphate-efficiency led to a reduction in height and in tillers. The absorption of nitrogen was found to depend on phosphorus concentration, and they concluded that phosphorus is not only useful in the early stages of growth, but may also be utilized at the later stages of development. Under phosphate-deficiency, accumulation of amides takes place, and protein synthesis is considerably reduced. Phosphate deficiency symptoms have also been examined at the Central Rice Research Institute (unpublished records) under solution culture technique. Phosphate deficient plants were stunted, had low tillering capacity, poor ear heads and low yield of grain. Upper leaves of phosphate deficient plants were narrow, short, stiff and straight. In early stages of deficiency, new leaves were bluish-green and lower part of the stem was coloured with light pinkish streaks. With advanced deficiency, upper leaves became deep bluish green in colour and older leaves started dying from tip downward. Colour of the dead leaves was purplish red. Roots of phosphate deficient plants were comparatively few in number and were coloured rust brown. Primary roots were elongated and secondary roots were few. Phosphate deficient plants had low content of both nitrogen and potash. Mgo content was also low, but silica content was high. High increase in phosphate supply, P 205, nitrogen, potash and Mgo uptake of plant increased and silica uptake fell to normal level.

Specific cases of phosphate-deficiency under field conditions are reported in the country, and are corrected by application of superphosphate or other soluble phosphatic fertilizers. Krishnamoorthy (*l.c.*) from Hyderabad State, reported deficiency symptoms of phosphate in transplanted rice crop as follows.

The transplanted crop appears normal till about a month, when the normal tillering phase should set in. At about this time, there is a sudden set-back in growth. A few tillers are produced, or none at all. The plants begin to die, giving the field a parched up appearance. The algal growth in water is scanty or none.

All the leaves, except a few at the growing point, are affected and start drying. Drying proceeds uniformly all through the width of the leaf, from tip downward. The first one or two leaves near the growing point are of a dark bluish colour, indicating nitrogen excess. Root growth is poor, and often an attack of *Alternaris* and or *Sclerotia* can be seen. Attacked plants produce a few earheads, the panicle is about two inches long and contains 10 to 12 grains only.

Krishnamoorthy (*l.c.*) further reports that a directly seeded crop suffers more than the transplanted one, and no improvement in the crop occurs on applying only nitrogenous fertilizers. The crop, however, responds to the application of phosphatic fertilizers in conjunction with nitrogenous fertilizers, and a combination of 45 lb. per acre to 3,652 lb. per acre.

Investigations on the effect of potassium deficiency on growth and nitrogen metabolism of rice plant have been conducted by Sircar and Dutta (1957) in sand culture trials. They reported that the potassium-starved plants exhibited reduction in stem-length and increased succulence. Stems of potassium-deficient plants were slender and displayed development of minute brown streaks on their surface. The leaves were dull green to yellow in colour and some of them showed the formation of red patches on the edge, possibly due to development of anthocyanin. The older leaves were first affected by potassium starvation; they rolled up and scorched, commencing at the tip and proceeding downward to the base. The leaves at emergence were green but became chlorotic when unfolded. The degree of potassium deficiency was found more harmful to growth in ammonium nitrate culture than in sodium nitrate culture. They also found more total and protein nitrogen in high potassium plants and created amide, amino, nitrate and nitrite nitrogen in low potassium plants.

Potassium deficiency symptoms, observed at the Central Rice Research Institute (unpublished records) from a series of water culture studies, were as follows. Potassium-starved plants were dwarfish, but tillering was not seriously affected. The upper leaves of the potassium-deficient plants were deep green, soft and small, and leaf blades were wavy in appearance. The older leaves started drying from tip downwards and the colour of dead leaves was dirty yellow. Younger leaves, however, continued to be deep green in colour. Flowering in the potash-deficient plants was delayed and panicles formed were few and poor in yield. Potash-starved plants had also higher content of both P_2O_5 and nitrogen, which became normal when adequate potash was supplied. Mgo, Cao and Sio_2 content of low-potash plants was also high and came down progressively with increased potash uptake by the land.

Potassium deficiency in rice crop has not been observed under field conditions in our country, as most of the soils are considered to have enough supplies of available potassium. Mukerjee (1955) from Bihar has, however, reported potassium response to rice in some soils of the State.

Ghosh (1954) studied the effect of varying levels of water on the growth of rice in relation to nitrogen absorption. He reported that the number of tillers, total leaf-area, total dry matter and grain-yields increased in treatments with water up to the surface soil level, but gradually decreased with the rise of water level. The plant

height and individual leaf-area were found to increase with the rise of water level, and the water-content of stem and leaf were also similarly affected. The nitrogen content and dry weight of roots decreased with increasing water level, probably because the water-logged state, resulting in reduced soil aeration, checked the root-growth and the uptake of nitrogen. In a comparatively dry state also, root-growth was restricted due to insufficient water supply, although the nitrogen-content in the root was found to be high. The percentage of nitrogen in both the stem and leaf increased with the water logged condition. The plant growth, as indicated by tillering was not correspondingly increased, but was influenced by the increasing water level and, therefore, the nitrogen was not utilized fully and accumulated in the stem and leaf. It is suggested that it is necessary to maintain different water levels at the different stages of growth and development of the crop. Two to three inches of water in the field for two weeks after transplantation, followed by drainage and maintenance of field moisture up to the surface of soil for another five to wix weeks for *aus*, and seven to eight weeks for *aman* would give optimum tillering. Standing water at the time of ear-emergence and grain-formation had, however, some beneficial effect.

The role of silicon in rice plant nutrition has been investigated by Sreenivasan (1936). He reported increased availability of silica under wet conditions than under a dry state of soil. Comparative studies on the intake of silica under dry and wet conditions have shown that the plant absorbed greater quantities of silica under wet conditions than under a dry state of soil. The growth and yield of the rice plant increased both under dry and flooded conditions with the application of sodium silicate, but the response was greater in the dry than in the flooded series.

MICRO-NUTRIENTS

Investigations on the role of micro-nutrients in growth and development of rice plant, in our country, have been rather few. Manganese, copper, boron and sulphur have received some attention, and effect of these on plant growth has been studied both under sand culture and field conditions.

Patnaik (1955) from a series of sand culture studies reported that with no manganese added to culture solution, growth of rice plant was poor, plants were light green in colour and leaves were spotted in appearance. When manganese was added in concentration of 1 ppm., yield was nearly doubled. A concentration of manganese of over 5 ppm. was toxic for growth, and the plants suffering from manganese toxicity were stunted and chlorotic. Patnaik (1950) has also reported on the influence of manganese on catalase activity of root and shoot of the rice plant, which increased with increase in the manganese concentration and dropped when critical concentration was reached.

Specific cases of manganese deficiency under field conditions are, however, rare, as under the water-logged conditions of rice soils, manganese readily goes in solution and becomes available for crop uptake. Manganese deficiency may, however occur on sandy soils, particularly under upland rice cultivation. Manganese toxicity conditions, on the other hand, are reported to occur in some black soils of Hyderabad (Krishnamoorthy, 1955). When these soils were brought freshly under water-logged conditions, the rice crop appeared to suffer from an

excessive uptake of manganese, and this was particularly pronounced under poor drainage conditions. Symptoms of manganese toxicity, developed on black soils of Hyderabad, were as follows.

1. Drying of leaves from apex downward.
2. Bleaching of chlorophyll from leaf-margin towards the midrib. In some cases, the chlorophyll in the entire lamina, except the midrib was bleached.
3. Premature death of the leaf.
4. In severely affected plants, side tillers also died.

Manganese toxicity under such conditions was prevented by providing shallow surface drains in the soil. When the crop was found to suffer from toxic symptoms, alternate wetting and drying of soil also helped to a great extent.

Patnaik (1955) has also reported on the influence of copper and boron on rice growth. He found that when no copper was given in culture solution, plants were yellowish green in colour and there was a marked retardation of chlorophyll synthesis. Rate of growth was greatly reduced and leaves began to dry up as if suffering from severe drought. Plants supplied with 0.001 to 0.1 ppm. of copper were normal in colour and vigorous in growth. As regards boron, Patnaik reported that with the absence of boron in culture solution, the plant growth was very slow. The apex of the leaves began to die and there were brown spots on the leaf lamina. Addition of boron greatly increased plant growth, and 1 ppm. was considered optimum for growth. Boron was also reported by him to be associated with catalase activity of root and shoot. Copper and boron deficiencies have, however, not been reported under field conditions, but some gain in the yield of grain is reported by application of these micro-nutrients in certain soils.

It is reported from Madras (Agricultural Year Book 1917), that an application of copper sulphate in irrigation water benefited rice crop. Joshi and Joshi (1952) obtained yield response due to small dressings of copper sulphate on poor soils in Kolaba and Ratnagiri districts along the sea coast of Bombay State. Govindarajan (1954) from Mysore also reported yield increase of 15 to 20 per cent. by application of five pounds of copper sulphate per acre.

Karunakar (1952) from Coimbatore has observed beneficial effects due to spraying of rice crop with copper sulphate, manganese sulphate and zinc sulphate, used singly and in combination. He obtained yield increase ranging from 10 to 28 per cent. due to spraying of micro-nutrient solutions in concentration of ten to twenty pounds in 100 gallons of water. At the Central Rice Research Institute (Annual Report, 1949-50 to 1953-54) also, trials with micro-nutrients applied to soil, sprayed on the crop and used in seed treatment prior to sowing have been conducted. Copper sulphate and borax applied to soil at 10 to 20 lb. per acre have given small yield responses particularly on upland rice soils of poor fertility. Spraying the crop with solution of copper sulphate and zinc sulphate has also shown small yield increase. Seed treatment with micro-nutrient solutions prior to sowing, however, showed no beneficial effects. Yield increases obtained at the Central Rice Reseach Institute with micro-nutrients have varied considerably from year to year from no increase in certain years to 10 to 30 per cent. increase in other years.

Sulphur deficiency has been reported by Saran (1949) from Bihar to be the cause of a disease locally known as *Dakhina*, *Ukra* or *Chatra*. A general yellowing of the leaves and subsequent drying up of leaf tips were the characteristic symptoms observed. The drying up of leaves proceeded from tip downward and ultimately the plants presented a withered appearance. Yield of the affected crop was reduced, and in severe cases complete loss of grain occurred. No specific organism was found to be associated with the disease. Soil analysis indicated a sulphur deficiency and application of sulphates to soil helped plants to recover and become green. Dressings of sodium, aluminium and ammonium sulphate were found to control the disorder and increase crop yield.

VERNALIZATION AND PHOTOPERIODISM

Rice in India is subject to varying photoperiods in different seasons and different latitudes, and the response of rice varieties to this environmental factor is a subject of importance. It is known that small differences in natural day-lengths have a marked influence on the flowering duration of rice varieties, and that photo periodism in combination with temperature affects the physiology and yield of the varieties. The earliest work on this subject in India was by Alam and Saran (1938), who found that by increasing the day-length, flowering was delayed, while by decreasing it, the plants were induced to flower earlier. Prior to this, research had been done on the adaptation of varieties to different seasons, and their duration with different dates of planting. A grouping of varieties into 'season-bound' and 'period-fixed' classes had been adopted, and it was recorded that the former included all the long-duration winter rices.

With the development of vernalization techniques in temperate countries, particularly with reference to wheat, parallel experiments on rice were started in India. Germinating seeds were subjected to low temperatures for different periods, and subsequently grown normally. Parthasarathy (1940) compared seeds kept at 10°C and 20°C for three weeks with control, and reported a small reduction in the flowering duration in vernalized plants. Alam (1940) subjected seeds to 0°C to 2°C and 10°C to 12°C for varying priods, and found no differences in duration of the vernalized and the control plants, but the plants treated at 10°C to 12°C were taller and gave higher yield. Hedayetullah and Sen (1941) subjected germinating rice seeds to 0°C, 11°C and 29°C for different periods and found that seeds vernalized at 29°C were earlier in flowering. Sircar and Parija (1945) and Kar and Adhikary (1945) reported that a low-temperature treatment of rice seedlings delayed ear emergence, while Parija (1943) and Ghosh (1949) found that high temperature treatments hastened flowering. Sircar (1948), discussing the results of vernalization experiments, pointed out that the temperature requirement of the rice plant throughout its life cycle is 20°C to 37°C, and at no stage of its development does it benefit by temperature below 15°C. Sircar (*l.c.*) pointed out that photoperiod was of greater importance than vernalization in the initiation of flowering in rice, and showed that the classification of rice into summer and winter varieties was based on their adaptation to flower under long-day and short-day conditions respectively.

Sircar (1949) concluded that (i) the response to photoperiods was a varietal character, (*ii*) the response to short day-lengths was of a quantitative nature, as the

degree of earliness increased with the duration of the treatment, (*iii*) all winter rices were short-day plants, and (*iv*) tillers formed subsequent to the short-day treatment did not show any response, but flowered at a period normal for the variety. By subjecting the variety *Rupsail* to a continued short-day treatment, Sircar and Parija (1945) effected a reduction in the flowering duration from the normal 133 days to 47. The reduction of duration was accompanied by a curtailment in the vegetative growth of the main shoot. Sircar and Ghosh (1947) found that a short-day treatment of summer varieties delayed flowering, and also annulled the earliness induced by high-temperature vernalization.

Experiments have been conducted on the optimum age of seedlings to be treated, the minimum duration of treatment to secure response, and also on the effect of different lengths of photoperiods. Misra (1952, 1955a) subjected seedlings of different ages to short day-lengths. He found that treatments applied to seedlings before 30 days' growth delayed flowering, while subsequent treatments hastened it. By comparing the effect of short-day treatments to plants 30, 40, 50, 60, 70 and 80 days old, he found that the acceleration of flowering by short-days was inversely correlated to the age of plants, and varieties differed in their response. Misro *et al.* (1953) found the optimum age of seedlings for securing photoperiod response to be 14 days for the the variety *Baok*, and 35 days for the strain *T.1242*.

Saran (1950) reported that short-day treatment for 15 days was the minimum period required to induce early flowering. An experiment comparing the effects of eight and ten hour photoperiods given for varying number of days was conducted at the Central Rice Research Institute (Ghose *et al.* 1952). Using one variety, they subjected 30 days old seedlings to eight and ten hour photoperiods, either in the forenoon or in the afternoon. The duration of the photoperiod treatment was 20, 30 and 40 days. They found that the forenoon exposure accelerated the flowering more than the afternoon exposure, and there was no significant difference between eight and ten hours photoperiods and between 20, 30 40-day treatments.

The response of 20 *indica* varieties from eight different countries to photoperiods of 10½, 11½, 12½ and natural day-length was studied at the Central Rice Research Institute (Annual Report, 1953-54). Both early and late varieties were included, and all showed sensitivity to photoperiod. All the treated early varieties flowered earlier than the control, and the response increased with a decreasing light period. In late varieties, 10½ and 11½ hour treatments hastened flowering, but the 12½ hour treatment delayed flowering.

An analysis of the quantitative response of medium and long duration varieties to short-day treatment was made by Ghose and Shastry (1954). In this experiment, 50 varieties of the *indica* sub-species from different countries were used, and 30 days old seedlings were subjected to eight-hour day-lengths for 20 days. The experiment was conducted for two years, and periodical sowings were made. The normal duration of the varieties at Cuttack were determined with sowings made in the middle of June. All the 50 varieties, the normal duration of which ranged from 76 to 180 days, showed acceleration of flowering following short-day treatment. All the varieties sown in any one month, when given the short-day treatment, came to flower within a short period of one another, and in April sowings, the differences did not exceed ten days. The mean flowering duration of the treated varieties varied

with the season of growth, the duration being 64 days for April sowings, and 91 days for November sowings. This difference is caused by temperature conditions in growth. A statistical study of the data showed that the longer the normal duration of a variety, the greater was its response to eight-hour photoperiod, and the regression value of photoperiod response over the normal duration of varieties approached unity.

In general, it has been found that the long-duration (season bound) *indica* varieties were markedly sensitive to short day-lengths, while the short and medium-duration varieties were less so. Exposure of 30 to 35 days old seedlings to short day-length generally reduced the nomal flowering duration of all varieties. However, Misra working with a number of *indica* varieties subjected to short day photoperiods, obtained different results. Misra (1955b, 1955c) and Misra and Samantrai (1955b) found that in six early varieties of Uttar Pradesh and one of Orissa, short day treatment increased the flowering duration. Misra (1954) subjected four long-duration varieties of Orissa to short day-length and found that they differed in response. The varieties *GN.3*, *SR.26B* and *FR.13A*, showed delayed ear emergence after short day treatment in seedling stage. In this experiment, continuous short day treatment of *FR.43B* resulted in 15 per cent. of the plants showing a reduction in duration by 68 days, while the remaining 85 per cent. showing the reduction by 5 days.

The response of some wild species of *Oryza* to short day was studied at the Central Rice Research Institute. The species *O. officinalis*, *O. eichingeri*, *O. latifolia* and *O. ridleyi* are season bound and their flowering was hastened by short day treatments. The species *O. breviligulata* and *O. australiensis* are of short duration and are comparable to 'period fixed' rice varieties. Shah (1955) found that in both these species flowering duration was slightly reduced by short day treatment.

The effect of long day-lengths on early, medium and late *indica* varieties has been studied by Misra (1955d, 1955e, 1956). With early varieties, a continuous light period for three weeks and six weeks given to week-old seedlings slightly retarded the flowering duration. With medium-duration varieties, similar photoperiod treatments for three weeks hastened flowering, while prolonging the treatment to five and six weeks retarded flowering. With late varieties, continuous photoperiods for three and six weeks did not alter the flowering duration.

Studies on the nutrition and growth of rice plants under different photoperiods have been commenced at the Central Rice Research Institute. In one experiment, a *japonica* variety and an *indica* short-duration variety were subjected to 8 hour and 16-hour photoperiods, and normal day-lengths in the January-to-April season. Three levels of nitrogenous manure were applied, and the flowering duration as well as tillering were studied. The varieties did not flower under the 16-hour photoperiod. The short-day treatment hastened flowering, the response being greater in the *indica* variety. The degree of manuring did not affect the flowering duration, but the mean number of tillers increased with the levels of nitrogen. The short as well as long day-length reduced the average number of tillers per plant, and this was markedly so under the short day-length.

RESISTANCE TO SALINITY

Rice varieties known to be resistant to soil salinity are cultivated in many localities in India, where the common varieties cannot be grown profitably. Physiological studies of salt tolerance have been reported by Alam (1940), Parija (quoted by Ramiah 1953a), Chalam (1954) and Desai *et al.* (1957). Alam found that by soaking seeds in 0.1 per cent. salt solution the seedlings from treated seeds could be grown in pots containing 0.35 per cent. salt. He also reported that the seeds from these could be germinated in stronger salt solution than in the preceding generation. Parija found that soaking seeds in 1.7 per cent. salt solution enabled the treated plants to tolerate greater amount of salinity than control. Parija as well as Chalam have reported the following differences between salt resistant and non-resistant varieties. The exodermis layer of roots of resistant varieties was considerably suberized as compared to non-resistant varieties, but suberin developed in the latter under saline conditions. The leaf exudate of salt resistant varieties contains sodium chloride. The resistant varieties absorbed more sodium chloride and had higher salt content in shoots than the non-resistant ones.

Desai *et al.* (1957) have observed the effect of salt in irrigation water on rice growth and yield. A short-duration variety *HR.19* was used as test crop in pot cultures. They found that this rice could tolerate a concentration of 0.2 per cent. sodium chloride in irrigation water; panicle numbers declined progressively with increased concentrations up to 0.5 per cent. and 1.0 per cent. concentration was fatal. The above limits were in respect of crop grown in rainy season, while in summer, concentrations above 0.3 per cent. were highly injurious.

RESISTANCE TO DROUGHT

Rice varieties differ in their resistance to drought. Ramiah (1953a) reviewing the work on the physiology of drought-resistance has cited the work of Hector in Bengal who found that drought-resistant or upland varieties had higher osmotic pressure in their cells than the non-resistant or lowland varieties. Hector also found that application of phosphatic manure reduced the water requirement of rice plants. Alam (1937, 1938, 1940) studied the water requirements of different varieties of rice by obtaining the ratio between total amount of water transpired and dry matter formed. He found that drought-resistant varieties had a consistently lower water requirement than the non-resistant varieties. He also found that selection for drought-resistance could be made by testing survival and recovery of plants subjected to permanent wilting. He found that manuring in general, and farmyard manuring in particular, lowered the water requirement of plants in addition to increasing their yield. Parija and Pillay (1945) tested the effect of seed treatment on the water economy of plants raised from treated seeds. They soaked the seeds for 24 hours, air-dried them for six to eight hours, oven-dried them for 24 hours at 40° to 42°C, and grew the plants in pot cultures with limited water supply. The plants from treated seeds were more drought-resistant than the control plants, and had reduced water requirement up to maturity.

Rajagopalan (1957a, 1957b) compared drought-resistant and susceptible varieties with respect to their root development and osmotic pressure of expressed cell sap. He found that under similar puddle conditions the resistant varieties had a more

extensive root system which grew to greater depth and gave a greater root/shoot ratio than the susceptible varieties. He also found that the osmotic pressure of cell sap of roots was higher in the resistant types. This difference was present in the cell sap of shoots also in the short-duration varieties, but not in the medium-duration varieties.

SEED VIABILITY

The viability of rice seeds in storage is controlled both by genetic and environmental factors. Varieties differ considerably in the rate of loss of viability in storage and dormancy is one of the factors influencing this (Sahadevan and Narasinga Rao 1947). The short-duration varieties are mostly non-dormant and lose their viability when the seeds have to be stored during a rainy season. Such storage is necessary when a second crop variety harvested in April or May has to be kept during the monsoon months for sowing in December or January. The importance of this problem in Malabar and Mysore has been pointed out by Sahadevan and Narasinga Rao (*l.c.*) and by Sahadevan (1953).

The moisture content of seeds is a factor which markedly affects their viability. Alam (1938) and Saran (1945) found that seed viability can be prolonged beyond the normal of eight to nine months either by complete sun-drying and storing in airtight containers or by storing with a desiccating agent. They also reported that the moisture content of seed stored by the method described above was reduced from the normal 10 to 12 per cent. to 3.6 per cent. However, they have not described the method adopted for determining the moisture percentage. Madras Agricultural Department records (memoirs 1954) state that dryage of paddy after harvest varies from 9 to 15 per cent. and that sun-dried seeds can increase in weight under storage in humid conditions. Sahadevan and Narasinga Rao (1947) and Sahadevan (1953) found that the seeds stored in sacks or straw bundles lost their viability in rainy period and attributed this to moisture absorption from air.

Ramiah and Padmanabhan (1949) and Padmanabhan (1956) found that treatment of seeds with some fungicides helped in prolonging their viability during storage through the monsoon period. Of the fungicides tried, cuprocide, which is a copper-oxide preparation, was found to be most effective in this respect. Spergon, phygon and arasan were also somewhat effective. The dose of the fungicide appeared to be important, the most effective dose being 1/500 by weight of seeds. Rice varieties seemed to differ in their response to fungicidal treatment. Some superfine varieties having thin long grains with finely pointed ends lost their viability rapidly during storage through the monsoon period in spite of fungicidal treatment.

Sahadevan (1953) concluded that surface borne moulds could not be the cause of deterioration in viability of rice seeds, since seeds treated with 'Agrosan GN' also lost their viability in storage. Padmanabhan (1957) studied the relation between loss in viability sustained by rice seeds in storage and their moisture contents and also the relation between such loss in viability as occurred in the experiment and mould activity. He found that the moisture content of sun—dried rice seeds ranged from 10.00 per cent. (in *T.1145*) to 13.5 per cent. (in *T.90*) amongst the five varieties he studied. During storage in containers maintained at 10, 25, 50, 75, 90 and 100 per cent. relative humidity levels, the seeds lost their viability in the last

three levels. The levels of moisture contents reached by the five varieties varied widely. Periodical isolation tests showed that the loss in viability had occurred without the intervention of moulds. Moulds were detected in rice seeds stored in 100 per cent. relative humidity level, long after the seeds had lost their viability.

CHAPTER 14

AGRONOMY

Next only to water, it is the use of manures and fertilizers and the adoption of better cultural methods which have a great bearing on the yield of rice. Before the establishment of Agricultural Department in most rice-growing areas of the country, no manure or fertilizer was used, excepting small quantities of available farmyard manure. Mostly the traditional method of broadcasting of seed, followed by hand weeding, was adopted. As a result of research work carried out in the country during the last three to four decades, improved methods of cultivation suitable for the conditions existing in the different areas, have been evolved and the application of suitable manures and fertilizers is being advocated for increased rice production.

The natural fertility of the soil is usually determined by the chemical analysis of the soils, e.g., the amount of available nitrogen, phosphorus and potash, the base exchange properties, etc. The collection of such comprehensive data for different soil types for the size of a country like India is likely to take several decades. Under the present conditions, therefore, the schedules of fertilizer requirements for the different areas will rest upon the experimental evidence of the average yield responses obtained in a particular locality, soil type and environmental conditions. It is assumed that the response to a fertilizer, supplying a certain nutrient, is likely to vary inversely with the initial fertility status of the soil and its yielding capacity. The plant food status of the soil estimated this way is expressed only in qualitative or relative terms, but the great advantage of using fertilizer experiments as 'soil tests' is that the results are directly applicable in practice. A large number of manurial experiments on rice have been conducted under different soil and climatic conditions by the Agricultural Departments in various States. The results of the earlier experiments were reviewed by Sethi (1940). Since then, properly planned and coordinated experiments have been conducted at different research stations with different fertilizers, which have been reviewed by Sethi *et al.* (1952). Most of these experiments were conducted on Government Farms, where the general level of fertility is usually high, and improved methods of cultivation are practised. In recent years, more emphasis has been laid on the yield responses obtained on cultivators' fields, and a large number of simple 'soil test' experiments are being conducted in various rice-growing areas to get specific information on (i) how much increase in yield can be obtained through fertilization, (ii) which fertilizer materials are useful and (iii) when and how these fertilizers can be used. As a result of these experiments, a useful body of information has already accumulated. Plans have been further developed for conducting nation-wide 'soil test' experiments, to get more comprehensive data on the average response to the application of various fertilizers under different soil, climatic and water conditions. The data, when available, would be very valuable for formulating a national fertilizer policy.

RESULTS OF MANURIAL EXPERIMENTS

As a result of the manurial experiments on rice, it has been established that the application of both organic manures and inorganic fertilizers, particularly nitrogenous, gives appreciable increase in yield. The rate of response, however, varies with the initial fertility of the soil, season, method and time of application. As judged from the general order of responses to organic manures and the three major plant nutrients, e.g., nitrogen, phosphate and potash, it is clear that rice soils are mostly deficient in organic matter and nitrogen and moderately deficient in phosphate, but well supplied with potash. Recent experiments on cultivators' fields in some of the States, however, indicate that phosphate application in addition to nitrogen gives additional response, and potash, in certain localities, is beneficial. The application of calcium has also a beneficial effect, particularly on acid soils, and for the mineralization of the soil nitrogen.

Nitrogen, the most essential nutrient for the growth of the plant, generally occurs only in small quantities in organic combination in the soil. During the process of decomposition of the organic matter, nitrogen is liberated as ammonia, and subsequently converted into the soluble nitrate form. The level of crop production is often dependent on the capacity of the soil to produce and accumulate this form of readily usable nitrogen. As reported by Dastur and Malkani (1933) and Dastur and Kalyani (1934), the rice plant can absorb nitrogen in ammoniacal form in the earlier stages, and nitrate form in the later stages of its growth. Rice soils in India are generally deficient in nitrogen, and contain, on an average, 0·04 per cent. of nitrogen. The average crop of rice removes about 35 pounds of nitrogen from the soil every year, and it is found necessary to apply nitrogen in one form or the other to maintain the fertility and productive capacity of the soil. The nitrogen can be applied both in organic and inorganic forms.

ORGANIC MANURES

In the high temperatures of the tropical region, organic matter in the soil decomposes rapidly and there is, therefore, a greater need for replenishing the organic matter. Bulky organic manures, though slow in action as compared to inorganic fertilizers, benefit the soil by building up its fertility, and besides supplying the various nutrients needed by the plant, are the source of humus which supplies the food energy material needed for the development of soil organisms. There are bulky organic manures like cattle manure (F.Y.M.), compost and green manures, and concentrated organic manures like oilcakes.

Cattle Manure and Compost. They are usually applied before transplanting, as they require some time to decompose and become available to the plant. The yield responses of rice obtained with compost application in most of the short-term experiments are usually of a lower order as compared to ammonium sulphate. The main reason for this appears to be that the quantity of F.Y.M. or compost applied is calculated on the equivalent nitrogen basis as found in artificial fertilizers. While nitrogen in the latter is available to the plant immediately on application, in the case of cattle manure or compost, it becomes gradually available. The effect of application of compost, therefore, can only be determined by conducting long-term experiments.

A permanent experiment, in progress at the Central Rice Research Institute, to study the effect of continuous application of ammonium sulphate in conjunction with compost on rice yields revealed that the average response to compost, applied at the rate of 8,000 pounds per acre to the same plots every year, was lower than that of ammonium sulphate during the first two to three years, but in later years, the response to compost has been higher than that for ammonium sulphate as seen from Table 21.

TABLE 21. EFFECT OF CONTINUOUS APPLICATION OF COMPOST AND AMMONIUM SULPHATE

Season	No manure (control) yield in lb. per acre	Response in lb. per acre		
		Compost at 8,000 lb. per acre	Ammonium Sulphate	
			20 lb. N.A.	40 lb. N.A.
1949—50	1,532	211	92	455
1950—51	2,152	112	372	594
1951—52	1,988	331	351	407
1952—53	1,864	188	55	235
1953—54	2,162	692	567	1,070
1954—55	1,982	537	280	736
1955—56	1,653	491	432	643
1956—57	1,743	677	411	744

The quantity of cattle manure available for application in the country is, however, limited, and not sufficient even for a small fraction of the cultivated area.

Oilcakes. Concentrated organic manures like oilcakes contain a fairly high percentage of nitrogen, ranging from five to seven, and are quick-acting. A large number of experiments have been conducted in different States to study the performance of oilcakes as compared to inorganic and bulky manures, and the relative merits of various oilcakes. The response to oilcakes at almost all places is found to be practically the same as that for ammonium sulphate. The results of some of the experiments reported by Sethi *et al.* (1952) are given in Table 22.

Experiments to compare the relative merits of various oil-cakes with increasing doses of nitrogen have been conducted. Several oilcakes like groundnut cake, castor cake, sesamum cake, mustard cake and *neem* (*Azadirachta indica*) cake were tested, according to their availability at the different places, on equal nitrogen basis. Increasing yield responses were obtained up to 60 pounds of N per acre. In general the various oilcakes did not indicate any appreciable difference in yield responses, and could be considered as of equal value. The choice of one or the other form of cake, therefore, will primarily depend upon the cost and availability. However, in view of the high cost of oilcakes and their utility as valuable concentrated feed for cattle, their extensive use as manure for the rice crop may not be feasible or economical.

TABLE 22. COMPARATIVE YIELDS (LB. PER ACRE) OBTAINED FROM THE APPLICATION OF AMMONIUM SULPHATE AND OILCAKES AT DIFFERENT LOCATIONS

Station	No manure (control)	Ammonium Sulphate	Oilcake	Level of N. in lb. per acre	Remarks
MADRAS					
Coimbatore	..	2,782	2,879	30	Average of 1938-41, groundnut cake.
MYSORE					
Irwin Canal Farm	2,140	3,047	3,179	15	1947-48, groundnut cake, 3,000 lb. of green leaves and 1 cwt. bonemeal were applied as a basal dose except to the control.
Nagenhally	1,746	2,187	2,067	15	do.
ORISSA					
Cuttack	2,269	2,736	2,673	30	Average of 1939-43 groundnut cake.
Central Rice Research Institute	2,075	2,555	2,512	40	Average of 1947-49 groundnut cake; transplanted crop.
do.	1,286	1,947	1,941	40	Average of 1947-49, groundnut cake; broadcast crop.
Berhampur	1,450	1,801	1,851	30	Average of 1939-44.
UTTAR PRADESH					
Nagina	1,460	1,955	1,839	50	Average of 1938-39, castor cake.
JAMMU & KASHMIR					
Kudwani	1,625	2,209	2,081	75	Average of 1944-48, rape cake.

Green Manures. The practice of green manuring is by no means a recent innovation in India. From very ancient times, the practice of burying leaves, twigs and loppings from trees has been followed by cultivators in areas near the forests, where such material is easily available. However, in common with other agricultural countries of the world, scientific development of this practice and growing green manure as a field crop are of recent origin. The agricultural excellence of green manuring is now fully appreciated in the major part of the country, and the practice has established itself firmly in most of the States. In view of the limited supplies of other organic matter as cattle manure and compost, more attention is

being paid to extend the use of green manuring in the country. However, green manuring is not universally adopted in general practice on account of the unavailability of suitable green manure crops, which can stand adverse climatic conditions during the dry period and fit into the rotation practices obtaining in the different regions. Inadequate supply of seed, cattle trespass and lack of irrigation facilities are some of the other obstacles in the way of the speedy extension of this beneficial practice.

Unlike cattle manure and compost, green manures are quick-acting, and make nitrogen available immediately on application, because of the narrow C/N ratio of about 10 to 15 :1. It has been recognized that bulky organic manures like compost, with wider C/N ratio of about 30 :1, when applied to fields are not mineralized quickly because of the formation of complex nitrogen bodies which temporarily lock up the available nitrogen in the soil. Such bulky organic manures, however, have a delayed and residual action as compared with inorganic fertilizers and green matter having a narrow C/N ratio. Experimental results in the country indicate that the leaf portion of green manure, which is rich in nitrogen, when incorporated into the rice soil with an abundance of water, decomposes in about four to five days and behaves like a quick-acting inorganic fertilizer in supplying available nitrogen immediately on application. The stem and other woody portions which are hard to decompose, however, take time, and respond as other slow-acting bulky organic manures like compost and F.Y.M., and make nitrogen available in later stages.

Green Manvring Plants Suited to Different Areas: A variety of green manure crops is available in the country, and the choice of a particular green manure crop for any area depends primarily on the local soil and water conditions, season, farming practices and the intensity of cropping. When it is not possible to raise a green manure crop *in situ*, it can be grown elsewhere, and the green matter transported to the field and ploughed in.

The crops commonly used for green manuring rice in India are sannhemp (*Crotalaria juncea*), *dhaincha* (*Sesbania aculeata*), *guar* (*Cyamopsis psoraloides*), *pillipesara* (*Phaseolus trilobus*), wild indigo (*Tephrosia purpurea*) and cowpeas (*Vigna sinensis*). *Sesbania speciosa*, introduced from Africa in recent years, has proved its usefulness as a green manure crop for varying soil and climatic conditions. The green manuring practices in the different States were reviewed by Mukherjee and Agarwal (1950).

In Madras, Andhra Pradesh, and Kerala, the most commonly grown green manures are sannhemp and *pillipesara* for heavy type of soil, *dhaincha* and *Sesbania speciosa* for normal and slightly saline and alkaline soils, and *Tephrosia purpurea* (wild indigo) and indigo for medium and light soils. Besides, the use of the leaves of quick-growing shrubs like *Gliricidia maculata* and *Adathoda vasica* is found beneficial. In areas of heavy rainfall where the growing of a green manure crop is usually not found possible, leaves and tender twigs of trees are cut and used for green manuring purposes. Of these, special mention may be made of the trees like *Albizzia lebbek*, *Cassia auriculata*, *Pongamia glabra*, *Cassia florida* and *Embelica officinalis*, (Sethi, 1940). Of these, *Embelica officinalis* was found to be the most effective in neutralizing the alkalinity of the soil. Besides these, weeds like *Croton sparsiflorous* and *Leucas aspera* are also employed for manuring purposes.

In Mysore, Andhra Pradesh and Madhya Pradesh, besides the common green manures crops like sannhemp, *dhaincha* and cowpea, crops like *Cassia tora* and *kodogira* Velvet beans (*Stizolobium deeringianum*) are also used for green manuring purposes. In the irrigated tracts of Mysore, green manure crop consisting of a mixture of sannhemp, cowpea, green gram (*Phaseolus aureus*), black gram (*Phaseolus mungo*) and horse gram (*Dolichos biflorus*) are usually grown in between rows of non-legumes like sorghum, sesamum or niger during summer, and incorporated in the fields prior to transplanting rice in the monsoon season. Besides these, green foliage from plants like *Pongamia glabra*, *Azadirachta indica* and *Cassia auriculata* is cut and incorporated as green manure.

In Bombay, besides *dhaincha* and sannhemp, *kulthi* (*Dolichos biflorus*), niger (*Guizotia abyssinica*) and wild indigo are also used as green manure crops for the rice areas. For upland areas, *Phaseolus trilobus* (*ran mutki*) is suitable. Leaves of a variety of trees like *Pongamia glabra*, *Alysicarpus belgaumensis* and *Calotropis gigantia* are also used.

In the north-east region of India, sannhemp and *dhaincha* are the common green manure crops, the former being used for dry areas and the latter for acid soils and wet areas.

In northern India besides sannhemp and *dhaincha*, *guar* is also extensively used. Other useful crops are *senji* (*Melilotus sp.*) for the alkaline patches of the Punjab, and lentil (*Lens esculentum*) for the Kashmir valley, where rice is grown at an elevation of 5,000 feet. Besides these, a number of non-leguminous crops like *bhung* (*Cannabis sativa*) are also used for green manuring purposes.

Investigations at the Central Rice Research Institute, Cuttack, showed that besides the above-mentioned green manure crops, recently introduced crops like *Aeschynomene americana* and *Phaseolus semierectus* are suitable for wet land rice soils. Investigations are also in progress to determine the suitability of various indigenous and exotic varieties of leguminous crops for wet land rice soils. The characteristics and performance of some of these crops are given in Appendix V.

Yield Responses to Green Manuring: A large number of experiments with green manures have been conducted in various States. There is a high response to green manuring in most of these experiments, but the yield increases vary considerably from place to place, as in the case of other manures and fertilizers. Sethi (1940) noted that green manuring increased the yield of paddy by 10 to 50 per cent. in Madras and Mysore, 12 to 33 per cent. (with 30 to 45 lb. N per acre) in Orissa, 20 per cent. (with sannhemp or *dhaincha* at the rate of 40 lb. N per acre) in Bihar, 23 per cent. in West Bengal and 57 to 90 per cent. (with sannhemp or *dhaincha*) in Uttar Pradesh. Green manuring is of the highest value in light soils and least in heavy soils. In Madras, an application of green matter at the rate of 4,000 to 6,000 lb. per acre to the rice crop in light soils gave an increased yield of 20 to 25 per cent. while in the heavy soils, it was only about 8 to 10 per cent. Sivaraman (1951) reported 10 to 40 per cent. increased yields of rice from incorporation of green leaves at 4,000 to 6,000 pounds per acre, obtained from *Sesbania speciosa* planted on field bunds and perennial shrubs like *Gliricidia maculata* planted on road sides.

The results of some of the experiments reported by Sethi *et al.* (1952) are given in Table 23.

TABLE 23. AVERAGE YIELD OF PADDY IN LB. PER ACRE WITH AND WITHOUT GREEN MANURING

Location	Kind of leaf	Green matter per acre in lb.	Yield in lb. per acre		Increase in lb. per acre	Percentage increase over Control
			Control	Green manure		
Central Rice Research Institute	*Dhaincha*	4,000	2,034	2,406	422	21
*MADRAS						
Anakapalli	Sannhemp	6,000	1,633	2,432	799	49
Aduthurai	do.	4,000	2,050	2,418	368	18
Coimbatore	do.	6,000	2,689	2,869	180	7
WEST BENGAL						
Chinsurah	*Dhaincha*	*in situ*	1,840	2,296	456	25
	Sannhemp	do.	1,840	2,184	344	19
Burdwan	*Dhaincha*	do.	2,082	2,464	382	18
	Sannhemp	do.	2,082	2,496	414	20
*ORISSA						
Cuttack	*Dhaincha*	do.	1,916	2,532	616	32
Berhampore	do.	do.	2,072	2,517	445	21
*UTTAR PRADESH						
Nagina	do.	do.	1,508	2,277	769	51
*BIHAR						
Sabour	*Dhaincha*	12,000	1,610	2,587	977	60
	Sannhemp	12,000	1,610	2,642	1032	63
*HYDERABAD						
Himayetsagar	Sannhemp	6,000	840	1,800	960	114
	Dhaincha	6,000	840	1,515	675	80
*BOMBAY						
Karjat	*Ipomea carnea*		2,650	3,350	700	26
*KASHMIR						
Kudwani	Lentil	*in situ*	1,625	2,504	879	54

*Data taken from Tables 9 and 10—*Manuring of Rice in India*—Sethi *et al.*, 1952.

It is seen from Table 23 that green manure invariably gives considerable increase in yield.

Time and Method of Burying Green Manure Crops: In order to determine the optimum age and time of burying the green manure crop, an experiment is in progress at the Central Rice Research Institute, Cuttack, in which 8 and 12 weeks old crop of *dhaincha* is buried, at planting, and four and eight weeks before the planting of the rice crop. The yields obtained with the different treatments are given in Table 24.

TABLE 24. EFFECT OF AGE AND TIME OF BURYING *Dhaincha* ON THE YIELD OF PADDY (AVERAGE OF TWO YEARS)

Treatment	Yield of paddy in lb. per acre	
	8 weeks	Age of crop 12 weeks
1. Control (No manure)		2,805
2. *Dhaincha* buried 8 weeks before planting	3,017	3,141
3. *Dhaincha* buried 4 weeks before planting	3,024	2,965
4. *Dhaincha* buried at planting	3,102	2,879

The above results indicate that the eight-week old *dhaincha* crop buried immediately before planting gave similar yield response as when buried four to eight weeks before planting. But in the case of the older crop of 12 weeks, burying 4 to 8 weeks before planting was advantageous. This shows that if the green manure is young and tender, it can be buried immediately before planting, but if it is old and woody, it should be ploughed under sufficiently in advance of planting.

Experiments conducted in the Punjab to determine the proper depth of burying *dhaincha* indicated that burying *dhaincha* at a depth of 10 inches gives the highest yield as seen from the results given below.

Depth of burying *dhaincha* in inches	Yield of paddy in lb. per acre
5	3,992
10	4,446
15	3,922

In actual practice, however, it is difficult to deposit the green matter at a particular depth, but care should be taken that it is not left exposed on the surface, and buried about 10 inches deep.

Intercropping of Green Manure with Rice: While the practice of growing a green manure crop and burying the same at the time of puddling is possible in a 'wet' land transplanted crop, it is not possible for the broadcast crop, which is generally sown in the season. For the broadcast crop, the sowing of *dhaincha* between the lines

of the rice crop or sowing *dhaincha* and rice mixed together and burying the green manure 4 to 6 weeks afterwards at the time of weeding, is found to benefit the rice crop. In the case of a ' semi-dry ' crop, *dhaincha* and rice could be sown broadcast and *dhaincha* buried under at the time of *beushan* operation, which is usually done 6 to 8 weeks after sowing, with 2 to 3 inches of water standing in the rice field.

An experiment to investigate the effect of intercropping of rice with *dhaincha* and burying the latter at *beushan* is in progress at the Central Rice Research Institute. In the experiment, ammonium sulphate and superphosphate were also applied in conjunction with green manuring. The results obtained are given in Table 25.

TABLE 25. EFFECT OF INTERCROPPING OF RICE WITH *Dhaincha* ON YIELD OF PADDY (AVERAGE OF THREE YEARS 1953-56)

Treatments	Yield of paddy in lb. per acre
1. Paddy	2,112
2. Paddy+*dhaincha*	2,478
3. Paddy+*dhaincha*+20 lb. N	2558
4. Paddy+*dhaincha*+50lt. P_2O_5	2,471
5. Paddy+*dhaincha*+20 lb. N+50 lb. P_2O_5	2,617
C.D. (0.05) per acre	255

The growing of *dhaincha* mixed with rice, and ploughing it under at the time of *beushan* increased the yield of rice significantly, and gave an increase of 366 lb. per acre. An additional application of 20 lb. of N and 50 lb. P_2O_5 per acre gave a further increase of 139 lb. per acre, but this difference was not found to be statistically significant.

INORGANIC OR COMMERCIAL FERTILIZERS

NITROGEN

An outstanding result obtained from the manurial experiments, conducted under a wide variety of soil and water conditions, is the universal response to nitrogen application, Extensive investigations have been conducted to determine (i) the relative efficiency of various nitrogenous fertilizers, (ii) the optimum dose of nitrogen and (iii) the best method and time of application.

Relative Efficiency of Different Nitrogenous Fertilizers. Experiments on relative efficiency of different fertilizers have been conducted at several research stations in the country. In earlier experiments, only a few of the fertilizers were tested, but in recent experiments more forms have been included. Ammonium sulphate being the most commonly used nitrogenous fertilizer, it has been taken as a standard for comparing the efficiency of the fertilizers.

1. *Ammonium Nitrate, Sodium Nitrate and Potassium Nitrate*: The results of some experiments with these fertilizers are given in Table 26.

TABLE 26. COMPARATIVE YIELD WITH VARIOUS NITROGENOUS FERTILIZERS

Stations	Yield of paddy in lb. per acre						Remarks
	Control	Amm. sulphate	Amm. nitrate	Sodium nitrate	Potassium nitrate	Level of N.	
MADRAS							
Pattambi*	2,040	2,470	2,260	..	..	30	1945-46—Ist crop
do.	2,010	2,550	2,500	..	..	30	1945-46—2nd crop
do.	1,252	1,657	..	1,457	..	30	1935-36
Coimbatore	2,587	3,251	..	2,770	..	30	Average of 1935-36 and 1936-37
Aduthurai	2,500	3,156	..	2,797	..	30	do.
ANDHRA							
Maruteru	2,207	2,321	2,552	..	..	30	1945-46—Ist crop
do.	1,449	1,861	1,781	..	..	30	Average of 1944-45 and 1945-46 —2nd crop
UTTAR PRADESH							
Nagina	1,461	1,955	..	..	1,680	50	Average of 1938-40
do.	1,322	1,935	1,815	..	..	30 and 60	Average of 1946-48
do.	1,530	2,222	..	..	1,707	50	Average of 1937-38
do.	2,272	2,823	..	2,368	..	50	Average of 1935-36 and 1936-37
do.	2,141	2,758	..	2,367	..	50	Average of 1933-34 to 1937-38
Gorakhpur	1,280	1,770	1,787	..	..	30 and 60	Average of 1947-49
BIHAR							
Sabour	..	2,121	..	1,818	..	20	Average of 1932-33 to 1934-35
WEST BENGAL							
Chinsurah	1,935	2,337	2,097	..	..	20,40 &60	Average of 1945-47
Burdwan	1,722	2,148	..	1,886	..	20	Average of 1950-52
do.	2,977	3,247	2,837	..	..	20 and 40	Average of 1952-53 on cultivators' fields
24 Parganas	1,353	2,050	1,550	..	..	20 and 40	do.
MYSORE							
Irwin Canal Farm	2,140	3,047	3,253	..	..	15	1947-48
Nagenhally	1,746	2,187	2,087	..	..	15	do.
ORISSA							
Sahaspur	2,213	2,891	2,621	..	..	20 and 40	Average of 1955-56
Central Rice Research Institute	2,037	2,634	2,325	2,077	..	20 and 40	Average of 1953-55

*Now in Kerala State

It will be seen from the above data that ammonium sulphate has proved to be the best among the fertilizers. Ammonium nitrate records practically the same yield as ammonium sulphate in Andhra Pradesh, Madras and Mysore, but at other places it has given a lower yield. Sodium nitrate and potassium nitrate have given practically no increase in yield.

2. *Urea*: The yield obtained with urea as compared to ammonium sulphate at different places are given in Table 27.

TABLE 27. COMPARATIVE YIELD WITH AMMONIUM SULPHATE AND UREA

Station	Yield of paddy in lb. per acre			Level of N	Remarks
	Control	Amm. Sulphate	Urea		
UTTAR PRADESH					
Nagina	1,461	1,955	1,833	50	Average of 1938-40
WEST BENGAL					
Burdwan	2,977	3,247	3,075	20 and 40	Average of 1952-53 Cultivators' fields
24 Parganas	1,353	2,050	1,878	20 and 40	do.
ORISSA					
Sahaspur	2,213	2,891	2,781	20 and 40	Average of 1955-56
Central Rice Research Institute	2,037	2,634	2,265	20 and 40	Average of 1953-54 to 1955-56

It will be seen from the Table 27 that urea has given less yield than ammonium sulphate.

However, the results of trials conducted by the Technical Co-operation Mission (TCM) on cultivators' fields in different parts of the country during the years 1953-54 to 1955-56 have shown that both ammonium sulphate and urea gave equal response at most of the places.

3. *Ammonium Phosphate, Niciphos and Cyanamides*: The yields with these fertilizers in comparison with ammonium sulphate are given in Table 28.

It will be seen that ammonium sulphate and niciphos are of equal efficiency except at Gaya, where better response was obtained with niciphos. Ammonium phosphate also is equally efficient as ammonium sulphate. Calcium cyanamide was tested at Nagina in Uttar Pradesh and at the Central Rice Research Institute and found to be less efficient than ammonium sulphate.

These experiments were conducted at different locations, and there was a considerable variation from year to year in the relative effect of the various fertilizers, so that the results are not strictly comparable. Nevertheless, they give certain definite indications, and the relative ratings for some of the fertilizers as measured by the response obtained are given in Table 29.

TABLE 28. YIELDS WITH DIFFERENT NITROGENOUS FERTILIZERS

Station	Control	Yield of paddy in lb. per acre					Remarks
		Amm. sulphate	Amm. phosphate	Niciphos	Cyana-mides	Level of N	
ASSAM							
Dabhoi	369	570	..	530	..	50	Average of 1040-41 and 1942-43 to 1944-45
Titabar	1,730	2,231	2,313	..	..	40	1948-49
BIHAR							
Gaya	839	1,262	..	1,478	..	20	Average of 1934-35 and 1936-38
do.	1,332	1,542	..	1,861	..	40	Average of 1939-41
Sabour	874	1,340	..	1,280	..	20	Average of 1934-35 and 1936-38
do.	1,713	2,161	..	2,277	..	40	Average of 1939-40 and 1940-41
Kanke	1,412	2,056	2,027	..	..	60	1945-46
UTTAR PRADESH							
Nagina	2,141	2,758	..	2,842	..	50	Average of 1933-34 to 1937-38
do.	1,461	1,955	..	..	1,779	50	Average of 1938-40
ORISSA							
Central Rice Research Institute	2,037	2,634	2,551	..	2,107	20 and 40	Average of 1953-54 to 1955-56

TABLE 29. RELATIVE RATINGS OF VARIOUS NITROGENOUS FERTILIZERS TAKING AMMONIUM SULPHATE AS 100

Fertilizer	Relative rating
Ammonium sulphate	100
Ammonium phosphate	98
Ammonium nitrate	72
Urea	65
Cyanamide	36
Potassium nitrate	33
Sodium nitrate	24

Similar results were reported earlier by Ramiah *et al.* (1952).

An experiment has been in progress at the Central Rice Research Institute for the last three years, where all the eight different nitrogenous fertilizers are being tested on equal nitrogen basis. The results obtained are given in Table 30.

TABLE 30. EFFICIENCY OF VARIOUS NITROGENOUS FERTILIZERS (AVERAGE OF 3 YEARS, 1953-56)

Fertilizers	Average nitrogen content (per cent.)	Yield of paddy in lb. per acre			Mean response in lb. per acre	Relative rating with amm. Sulphate as standard
		20 lb. N	40 lb. N	Mean		
1. Ammonium sulphate	20.0	2,506	2,761	2,634	597	100
2. Ammonium phosphate	11.0	2,453	2,648	2,551	514	86
3. Ammonium chloride	24.0	2,402	2,670	2,536	499	84
4. Ammonium sulphate-nitrate	26.0	2,445	2,555	2,520	483	81
5. Ammonium nitrate	33.0	2,297	2,355	2,325	288	48
6. Urea	42.0	2,083	2,447	2,265	228	38
7. Calcium cyanamide	21.0	1,986	2,228	2,107	70	12
8. Sodium nitrate	16.0	2,021	2,134	2,077	40	7
No manure (control)		2,037		2,037		

All the fertilizers except sodium nitrate and calcium cyanamide have given an appreciable yield response. Though the response obtained with ammonium sul-

phate was the highest, it was not significantly different from those obtained with ammonium phosphate, ammonium chloride and ammonium sulphate-nitrate. Vachhani and Rao (1956) also have reported that the application of ammonium chloride to rice has given a yield response similar to that given by ammonium sulphate. Ammonium phosphate, ammonium chloride and ammonium sulphate-nitrate can therefore, be used as alternative fertilizers for rice, their extensive use will, however, depend upon their comparative cost and availability.

4. *Anhydrous Ammonium*: It is the cheapest form of nitrogen, and the most concentrated of the nitrogen fertilizers, containing 82 per cent. of nitrogen. Experiments with this have been conducted at Mysore. Govinda Rajan (1956) has reported that by injecting anhydrous ammonia into the soil at a depth of 4 to 6 inches with a special equipment at the time of the puddling of the field, the yields obtained were similar to those obtained with the same quantity of nitrogen applied as ammonium sulphate. The average yields obtained are presented in Table 31.

TABLE 31. COMPARATIVE YIELDS WITH ANHYDROUS AMMONIA AND AMMONIUM SULPHATE

Treatment	Yield in lb. per acre		Remarks
	Grain	Straw	
Ammonium sulphate at 30 lb. N/A	2,733	6,618	Average of four experiments in Mysore State during 1954
Anhydrous ammonia at 30 lb. N/A	2,656	9,213	

The grain yields obtained with anhydrous ammonia was not significantly different from that obtained with sulphate of ammonia. The straw yields with anhydrous ammonia were found to be higher than that with ammonium sulphate.

Though anhydrous ammonia is found to be as efficient as ammonium sulphate, its application requires special equipment for injecting it into the soil at the required depth so that it is not lost into the air.

Optimum Dose of Nitrogen and the Rate of Response. The responses obtained with varying doses of nitrogen applied in the form of ammonium sulphate both at research stations and on cultivators' fields are given in Table 32.

It will be seen from the Table that varying results were obtained at different places, but the optimum dose appears to be between 20 to 60 lb. N per acre. The responses obtained are generally between 300 and 700 lb. of paddy per acre with the application of 20 to 40 lb. N per acre. However, high responses were obtained at the Rice Research Station at Karjat in Bombay and in the trials on cultivators' fields at Sahaspur in Orissa. The figures show that the average responses obtained with 20, 30, 40 and 60 lb. N per acre are 340, 421, 570 and 474 lb. per acre, respectively. Yates *et al.* (1953) have reported the average standardized response of 280 lb. per acre for 20 lb. N per acre. The results obtained from 7,000 experiments on cultivators' fields in Bihar with varying doses of nitrogen as ammonium sulphate as reported by Mukherjee (1953) reveal that high response ranging from 400 to 2,250 lb. per acre were obtained with 25 to 40 lb. nitrogen per acre.

TABLE 32. RESPONSE TO NITROGEN APPLIED AS AMMONIUM SULPHATE

Place	Control yield lb. per acre	Response to different levels of N in lb. per acre							S. E. of Response	Remarks
		20	30	40	60	80	90	120		
TRIPURA										
Agartala	1,970	358	—	472	—	—	—	—	708	1953-54 TCM trials
W. BENGAL										
Chinsurah	1,853	—	451	—	369	—	377	148	52.5	Average of 1945-55
Sriniketan	1,984	—	230	—	156	—	—	—	213	Average of 1948-53
Canning	1,263	—	287	—	443	—	—	—	—	Average of 1949-52
-do-	2,882	265	—	400	—	—	—	—	52.5	TCM trials 1953-54
BIHAR										
Gaya	1,040	—	440	—	622	—	—	—	—	Average of 1939-40 to 1941-42
do	916	69	—	283	25	—	—	—	—	Average of 1936-37 to 1938-39
Sabour	1,573	—	129	—	159	—	—	—	—	Average of 1939-40 to 1942-43
Raneswar	1,026	297	—	527	—	—	—	—	37	1953-54 TCM trials
ORISSA										
Sahaspur	1,986	490	—	735	—	—	—	—	—	Average of 1954-55
do	1,362	612	—	1,103	—	—	—	—	65	1953-54 TCM trials
Bhubaneswar	2,351	466	—	439	298	—	—	—	—	Average of 1954-56
Central Rice Research Institute	1,946	286	—	583	626	426	—	—	—	Average of 1949-54
ANDHRA										
Samalkota	1,975	105	—	653	—	—	—	—	216.5	1953-54 TCM trials
Maruter	2,882	265	—	400	—	—	—	—	52.5	1953-54 TCM trials

TABLE 32. (CONCLUDED) RESPONSE TO NITROGEN APPLIED AS AMMONIUM SULPHATE

Place	Control yield lb. per acre	Response to different levels of N in lb. per acre							S. E. of response	Remarks
		20	30	40	60	80	90	120		
MADRAS										
Pattambi*	2,040	—	430	—	—	—	—	—	—	1945-46 1st crop.
-do-	2,010	—	540	—	—	—	—	—	—	1945-46 2nd crop
Aduthurai	2,471	285	628	—	—	—	—	—	—	Average of 1935-36 to 1938-39
do	829	285	—	235	—	—	—	—	52.5	1953-54 TCM trials
MYSORE										
Ponnampet (Coorg) ..	2,478	320	—	463	—	—	—	—	140	1953-54 TCM trials
Shigmoga	1,264	300	—	456	—	—	—	—	43	-do-
MADHYA PRADESH										
Labhandi	648	675	—	—	—	—	—	—	—	Average of 1939-43
BOMBAY										
Karjat	2,204	—	—	1,341	1,410	—	—	—	—	Average of 1933-34 to 1935-36
HYDERABAD*										
Warangal	1,904	380	—	425	—	—	—	—	83	Average of 1933-34 to 1935-36
PUNJAB										
Gurdaspur	966	317	—	601	630	688	—	—	—	Average of 1951-54
KASHMIR										
Kudwani	1,596	—	649	—	—	—	—	—	—	Average of 1941-42 to 1947-48
Unweighted means ..		340	421	570	474	—	—	—	—	

*Now in Andhra Pradesh

In trials conducted by TCM on cultivators' fields in different parts of the country during the years 1953-54 to 1955-56, the average responses of 369 and 541 lb. of paddy per acre were obtained with 20 and 40 lb. N per acre, respectively.

In most of the places, higher yields were obtained up to 40 lb. N per acre, but due to the limited number of doses tried, the response trends calculated from those data may not be very trustworthy. However, at Chinsurah, in West Bengal and the Central Rice Research Institute, five graded doses of nitrogen as ammonium sulphate were tried for a number of years. The yield-dose relationships can be represented by second degree polynomial and the equations obtained are given below.

Chinsurah $Y = 1894.72 + 13.05X - 0.10X^2$

Central Rice Research Institute $Y = 1916.80 + 23.47X - 0.22X^2$

Where Y is the expected yield in pound per acre, and X is the level of nitrogen in pound per acre. Based on the above equations, the responses per pound of nitrogen obtained at various nitrogen levels at the two locations are given in Table 33.

TABLE 33. RESPONSE TO VARIOUS LEVELS OF NITROGEN APPLIED AS AMMONIUM SULPHATE AT VARIOUS NITROGEN LEVELS

Level of N in lb. per acre	Rate of response in lb. of paddy per acre per lb. of N.	
	Chinsurah	Central Rice Research Institute
10	12.0	21.3
20	11.0	19.1
30	10.0	16.9
40	9.1	14.7
50	8.0	12.5
60	7.0	10.3
70	6.0	8.1
80	5.1	6.0
90	4.0	Negative
120	1.1	Negative

The above data show that the rate of response was higher at lower levels of nitrogen application, and decreased with increase in level of nitrogen. At the Central Rice Research Institute, the rate of response was even negative beyond 80 lb. of N per acre. The optimum doses have been calculated to be 65 and 53 lb. N per acre at Chinsurah and the Central Rice Research Institute, respectively, giving the expected maximum yields of 2,320 and 2,543 lb. per acre.

The economics of fertilizer application depends upon the rate of response and the cost/price ratio of fertilizer and paddy. The current rice of ammonium sulphate (including transport and handling charges) is Rs. 380 per ton, and that of paddy

varies from Rs. 9.50 per maund (82 lb.) in Orissa to Rs. 12.88 per maund (82 lb.) in Madras (*Bulletin of Agricultural Prices*, Vol. 8, Nos. 13 and 16, 1958). Based on the mean responses (vide Table 32) the net profit accruing from the application of ammonium sulphate at various levels of nitrogen is given in Table 34.

TABLE 34. ECONOMICS OF AMMONIUM SULPHATE APPLICATION

	Nitrogen in lb. per acre applied as ammonium Sulphate		
	20	40	60
Response in lb. of paddy per acre	340	570	474
Value of the additional produce in Rs.	39 to 50	66 to 90	55 to 74
Cost of fertilizer in Rs. ..	17	34	51
Net profit per acre in Rs. ..	22 to 36	32 to 56	4 to 24

It is seen from the above table that ammonium sulphate application is profitable up to 40 lb. N per acre, beyond which it gives less return. Similar results have been reported by Sethi *et al.* (1952), Yates *et al.* (1953) and Vachhani (1952).

Method and Time of Application. a. *Deep Placement of Ammonium Sulphate*: To get the maximum benefit out of the fertilizer, it is necessary that an efficient and rational method of application is followed. The customary practice of applying ammonium sulphate consists of spreading the fertilizer on the wet soil surface after the crop is established. The fertilizer thus falls on the top oxidizing layer of the soil and gets oxidized to nitrate, which on going to the lower reducing zone, gets denitrified releasing free nitrogen which is lost in the air. Thus, by oxidation and subsequent reduction, a considerable amount of nitrogen is lost. Besides, there is also the danger of nitrogen being washed away in the surface-drained water, in case of rain immediately after the application of fertilizer. To prevent nitrogen losses, a subsurface or deep placement of sulphate of ammonia is followed. By this, all ammoniacal nitrogen of the fertilizer is placed in the reducing zone, where it remains stable, and gradually becomes available to the crop during the active vegetable period. Subsurface placement of the fertilizer also ensures better distribution in the root-zone, and prevents any loss by surface drain-off.

Subsurface placement is done in different ways, depending upon the local cultivation practices. In irrigated tracts where the water supply is assured, the fertilizer is applied under the plough furrow in the dry soil before flooding the land and making it ready for transplanting.

It is also applied as a basal dressing at the time of puddling and preparation of land for transplanting, provided there is not too much of water in the field. The fertilizer is applied on the surface and the land is cross-ploughed to mix the fertilizer with the whole plough slice, and prepared for planting.

Where the fertilizer cannot be applied prior to puddling because too much standing water in the field, it can be applied as a topdressing any time after planting

in the form of pellets. The fertilizer is mixed with soil in the ratio of 1 : 10 and made into a dough. Small pellets of a convenient size are then made and deposited in the soft mud, 1 to 2 inches deep between the rows of the crop.

Ramiah *et al.* (1951) recommended deep placement as a rational method of fertilizer application, and Abichandani (1953) reported that deep placement gave higher yields of both grain and straw than the customary surface application.

The results of a series of experiments conducted at the Central Rice Research Institute indicate that the subsurface application of ammonium sulphate, either as basal dressing in ' dry ' or 'wet ' soil, or as a topdressing in the form of pellets after planting was more beneficial than the customary surface application. Results obtained from an experiment conducted for four years is given in Table 35.

TABLE 35. SUBSURFACE 'DRY' APPLICATION OF AMMONIUM SULPHATE

Season	No manure (control) yield of paddy in lb. /acre	Response in lb. of paddy/acre Ammonium sulphate at 20 lb. N/A	
		Surface Application	Subsurface application
1949-50	1,538	169	259
1950-51	1,817	253	315
1951-52	2,160	98	230
1952-53	1,469	251	372
Mean	1,746	193	294
Response per lb. of Nitrogen	—	9.7	14.7

Thus, on an equal nitrogen basis, the subsurface ' dry ' basal dressing has given a higher yield response than the customary surface application after planting.

In another series of experiments, the subsurface 'wet' and pellet applications were tested in comparison with the customary surface application and results are given in Table 36.

It will be seen from Table 36 that on an equal nitrogen basis, both basal subsurface 'wet' application at planting and pellet deep-placement 3 to 4 weeks after planting have given higher yield responses than the customary surface application. Therefore, the subsurface application of ammonium sulphate is more beneficial.

b. *Fractional Application of Ammonium Sulphate*: Ammonium sulphate, being soluble and easily available to the plant, has to be applied at a stage when the plant is capable of making the best use of it. Usually the fertilizer is applied as a topdressing soon after the crop is established. Experiments to investigate the best time of application of ammonium sulphate have been carried out in various states. The results seem to vary at different places. While in some places the application of fertilizer at different stages of the plant growth does not bring about any effect, at others it shows marked difference. Again, at some places the total quantity applied at one time seems to do better than when it is applied at two

TABLE 36. SUBSURFACE 'WET' AND PELLET APPLICATION

Year	Variety	No manure (control) yield of paddy in lb./acre	Response in lb. of paddy/acre Ammonium sulphate at 20 lb. N/A		
			Customary surface application 3-4 week after planting	Basal subsurface 'wet' application at planting	Subsurface pellet application 3 to 4 weeks after planting
1950-51	C. 13	1747	135	—	262
1951-52	T. 90	2541	135	—	227
1952-53	T. 1242	2639	158	—	317
1953-54	T. 141	2579	216	432	629
1954-55	T. 141	2930	170	336	270
Mean ..		2487	163	384	341
Response per lb. of nitrogen		—	8.1	19.2	17.5

or three different times, and vice versa. Sethi *et al.* (1952), summarising the results of the large number of experiments in different parts of the country, observed that the effect of different times of application was not consistent and probably the weather conditions particularly the rainfall and the soil water conditions, may have a large effect on the time of application of the fertilizer.

To investigate this aspect further, a comprehensive experiment is being conducted at the Central Rice Research Institute, where the fertilizer is applied in relation to the growth of the crop, and the results so far obtained indicate that the application of a total quantity of 40 lb. N per acre in three split doses—half at planting, one fourth a month after planting and the rest two to three weeks before flowering—is more efficient than the application of the entire quantity in one dose. The Time of split dressings of the fertilizer coincides with active vegetative growth and tillering in the early stages and flower initiation at the later stages when the plant is capable of making a better use of the fertilizer applied.

PHOSPHORUS

The response of the rice crop to phosphatic fertilization in general has not been as large as in the case of nitrogen. Experimental evidence collected of late has shown that under cultivators' conditions, phosphate deficiencies occur, and yields can be pushed up by supplementing nitrogen with a dose of phosphatic fertilizer on many soils in the country, and that economic returns can be obtained from the use of these fertilizers. Prior to 1952, evidence collected from a large number of trials conducted at experimental stations all over the country, had shown that unlike nitrogen, phosphate generally gave no response except in certain places in the States of Madhya Pradesh, Bihar and Bombay. It was, therefore, concluded that phosphate did not give any yield-increase in alluvial paddy soils. Mukherjee (1955) conducted a series of trials on cultivators' fields in Bihar, and reported a positive response to the application of superphosphate on gneiss as well as alluvial

FIG. 36. The customary surface application of ammonium sulphate

FIG. 37. Subsurface dry application of ammonium sulphate

Fig. 38. Subsurface pellet application of ammonium Sulphate

soils of the State. He observed that the absence of response in the past on experimental stations might have been due to the higher fertility status of the soil, better system of cultivation and management obtained there. The results obtained by him are given in Table 37.

TABLE 37. RESPONSE TO PHOSPHATE APPLICATION IN BIHAR

Year of Trial	No. of experiments conducted	Average response in lb. of paddy per acre	
		20 lb. P_2O_5	40 lb. P_2S_5
1949-50	576	—	262
1950-51	1,334	—	246
1951-52	1,245	—	279
1952-53	625	—	246
1953-54	759	237	366
1954-55	710	270	344

Following the experiments in Bihar, trials on cultivators' fields were started all over India, and results from nine major rice-growing States showed that on an average, nitrogen alone gave a response of 145 lb. per acre, and nitrogen and phosphate in combination gave a yield increase of 255 lb. per acre, Raychaudhuri (1953). Extensive TCM trials conducted on cultivators' fields during 1953-54 to 1955-56 also showed a substantial response to phosphatic fertilization on various soil types in the country. Medium black soils of trap and gneiss origin, red gravelly and yellow soils, red loams, alluvial and coastal alluvial soils and lateritic soils, all show good response. The average response to phosphate fertilization on all types of soils under these trials on the cultivators' fields was 217 lb. of paddy for the 20 lb. P_2O_5 level and 307 lb. of paddy for the 40 lb. P_2O_5 level. The deep-placement of phosphatic fertilizers, superphosphate and ammophos was found superior to broadcast surface application.

A good response to the application of phosphate in combination with nitrogen is also reported by Desai *et al.* (1954) on the black soils of Hyderabad State. These soils ordinarily could not grow a crop of rice, but when fertilized with nitrogen and superphosphate, gave a considerable increase in yield.

The levels of phosphate recommended vary a little from place to place, but generally, 30 lb. of P_2O_5 per acre with 30 lb. N per acre is considered as a profitable level. All the phosphatic fertilizers are given as basal dressing at planting, and properly mixed up by cross-ploughing.

Efficiency of Different Phosphatic Fertilizers: The most commonly used phosphatic fertilizer is superphosphate, but bonemeal, rock phosphate and combined nitrogen and phosphatic fertilizers like ammophos and niciphos are also used. An experiment was conducted at the Central Rice Research Institute to investigate the relative efficiency of a number of phosphatic fertilizers. Superphosphate

of lime, bonemeal and six other mineral phosphates were tried on the equal basis of 30 lb. P_2O_5 per acre in a clay soil with low available phosphates. The results are given in Table 38.

TABLE 38. COMPARATIVE EFFICIENCY OF VARIOUS PHOSPHATIC FERTILIZERS

Phosphatic fertilizer	Total P_2O_5 content (per cent.)	Yield of paddy in lb. per acre	Percentage
1. Bonemeal	28 to 29	1,960	125.9
2. Superphosphate ..	18	1,891	121.5
3. Agrophos	25	1,829	117.5
4. Selectophos	24.5	1,778	114.2
5. Hyperphosphate ..	25 to 26	1,952	125.4
6. Hyperphosphate ..	26 to 27	1,757	112.9
7. Hyperphosphate ..	28 to 29	1,811	116.3
8. No Phosphate (control)	—	1,556	100.0

Note—Phosphatic fertilizers No. 3 to 7 are all mineral phosphates.

The above results indicate that phosphate application has given an average increase of 19 per cent. in yield, but there was no differential response with the various forms of the phosphatic fertilizers tried.

Seed-soaking in Nutrient Solution. Soaking rice seed in a nutrient solution of phosphate prior to sowing the crop directly in field, as a measure for increasing crop-yields, has been tried in the country, and found to be promising. Narayanan and Gopalkrishan (1949), from Coimbatore, conducted pot culture experiments with rice seed, and obtained 21.1 per cent. and 38.8 per cent. increase in grain yield by soaking seed in 10 and 20 per cent. solution of K_3PO_5 respectively, and a 10.9 per cent. increase with 20.0 per cent. solution of K_2HPO_4. Abichandani and Ramiah (1951) at Cuttack tried seed-soaking of rice in a number of nutrient solutions in trials extending over three years, and found that 10 and 20 per cent. solution of K_2HPO_4 gave promising results, increasing the yield of crop by 8 to 9 per cent.

POTASSIUM

Potassic fertilizers have generally given no response, except in Bihar. Experiments conducted on cultivators' fields (Mukherjee, 1955) have demonstrated that Bihar soils in general respond to potash application, and a yield increase of about 205 lb. per acre is obtained with 20 to 40 lb. of K_2O per acre. In recent TCM trials also, potash application at the levels of 20 and 40 lb. of K_2O per acre over a basal dressing of nitrogen and phosphate, gave a response ranging from 164 to 262 lb. of paddy per acre in the coastal areas of Kerala and parts of Bihar and Madhya Pradesh. The use of potash fertilizer for the rice crop, however, is not common in the country, and must await further country-wide and large-scale experimentation on the cultivators' fields.

LIME

Experiments on the application of lime to correct soil acidity and to counteract the physiologically acidic action due to the continuous use of sulphate of ammonia on soils have been pursued in the country, but the responses to lime application have been small and do not pay for the cost involved. The need for long-term experiments in this field has been felt, and trials have been laid out in the country. A trial in progress, at the Central Rice Research Institute, for the last eight years, to study the action of continuous use of sulphate of ammonia on the same land, has not shown any deleterious effect on the yield of the crop, and the lime applied every third year in this trial has shown no additional benefit. Lime at higher levels has, however, been found effective in mineralizing soil nitrogen, and making it readily available for the crop. A 2,000 lb. per acre lime level applied at puddling in the low land rice soil has given an additional yield increase of 395 lb. paddy per acre on an average of two years, and released additional nitrogen from the soil, equivalent to 30 lb. N per acre as sulphate of ammonia. This method of releasing additional nitrogen from the soil under low land conditions can be profitably used in places where lime is cheap and is readily available.

COMBINATION OF ORGANIC AND INORGANIC FERTILIZERS

Ammonium Sulphate with Farmyard Manure or Compost. Experiments with combinations of ammonium sulphate and cattle manure or compost were conducted at Chinsurah in West Bengal, the Central Rice Research Institute, Labhandi in Madhya Pradesh, and Kudwani in Kashmir.

At Chinsurah, graded doses of ammonium sulphate to supply 0, 30, 60, 90, and 120 lb. N per acre were applied without farmyard manure and with 8,000 lb. of farmyard manure as basal dressing. The experiment was conducted for a period of 10 years (1945-46 to 1955-56). The average yields are given in Table 39.

TABLE 39. EFFECT OF GRADED DOSES OF NITROGEN IN COMBINATION WITH F.Y.M. (CHINSURAH—AVERAGE OF 10 YEARS)

Basal dose	Average yield of paddy in lb./acre				
	Dose of N in lb./acre as ammonium sulphate				
	0	30	60	90	120
No manure	1,853	2,304	2,222	2,230	1,984
Farmyard manure at 8,000 lb./acre	2,181	2,427	2,206	1,943	1,714
Mean	2,017	2,366	2,214	2,087	1,849

The corresponding yield dose relationship is represented by the second degree polynomial as given below.

(a) No farmyard manure: $Y=1,894.72+13.05X-0.10X^2$

(b) With F.Y.M. @ 8,000 lb. acre: $Y=2,236.08+4.72X-0.08x^2$

The average response per pound of N applied as ammonium sulphate at different levels of N with and without farmyard manure is given in Table 40.

TABLE 40. RESPONSE IN LB. OF PADDY PER ACRE PER LB. OF N

Level of N in lb. per acre applied as ammonium sulphate	Response in lb. per acre	
	Without basal dressing	With basal dressing of F.Y.M. at 8,000 lb./acre
10	12.0	3.9
20	11.0	3.1
40	9.1	1.5
60	7.0	Negative
80	5.1	Negative

The above figures show that the response to ammonium sulphate is better at lower levels of N application, when applied alone. When applied over a basal dressing of 8,000 lb. of F.Y.M., the response obtained is too low, establishing the fact that any addition of ammonium sulphate over the basal dressing is not useful, and an increase in the dose of ammonium sulphate beyond 40 lb. N level gives a negative response. The maximum yields expected are 2,320 and 2,306 lb. per acre at 65 and 30 lb. N for no farmyard manure and farmyard manure plots, respectively.

At the Central Rice Research Institute, a similar experiment is in progress (since 1949), where graded doses of ammonium sulphate at 0, 20, 40, 60, and 80 lb. N/acre are being tested alone, and in combination with 8,000 lb. of compost per acre. The yields obtained are given in Table 41.

TABLE 41. EFFECT OF VARYING DOSES OF NITROGEN IN COMBINATION WITH COMPOST (CENTRAL RICE RESEARCH INSTITUTE—AVERAGE OF 7 YEARS)

Basal dose	Average yield of paddy in lb. per acre Dose of N as ammonium sulphate in lb./acre				
	0	20	40	60	80
No compost	1,946	2,232	2,529	2,572	2,372
Compost at 8,000 lb./acre	2,291	2,589	2,593	2,420	1,970
Mean ..	2,119	2,411	2,561	2,496	2,171

The yield dose relationship in both the cases is represented by a quadratic curve, and is given by the following equations.

(a) No compost: $Y=1916.80+23.47X-0.22X^2$

(b) With compost at 8,000 lb./A: $Y=2296.00+19.87X-0.299X^2$

From the above data, it will be seen that there is no appreciable increase in yield with nitrogen application beyond 40 lb. per acre in case of no compost plots, and 20 lb. per acre in plots receiving a basal dressing at 8,000 lb. of compost per acre. The average responses per lb. of N in the form of ammonium sulphate at different N levels when applied alone and in combination with compost are given in Table 42.

TABLE 42. RESPONSE IN LB. OF PADDY PER ACRE PER LB. OF N

Level of N in lb. per acre applied as ammonium sulphate	Without basal dressing	With basal dressing 8,000 lb. compost/acre
10	21.30	16.90
20	19.10	13.90
30	16.90	10.90
40	14.70	7.90
50	12.52	4.90
60	10.33	1.90
70	8.14	Negative
80	5.95	Negative

These figures show that the response to ammonium sulphate is better at the lower levels of nitrogen application when applied alone, or in conjunction with compost. Any additional application of nitrogen as ammonium sulphate does not benefit the crop, and gives a lower rate of response. The maximum yields expected are 2,546 and 2,626 lb./acre at 53 and 33 lb. of N per acre for the no-compost and compost plots, respectively. The effects of compost and ammonium sulphate are additive up to 20 lb. N level. With increase in the dose of ammonium sulphate beyond the dose corresponding to the maximum yield, compost-treated plots recorded a greater rate of decline in yield.

At the Labhandi Farm in Madhya Pradesh, 10 and 20 lb. N as ammonium sulphate and F.Y.M., and a combination of the two, were tried for five years (1939-43). The average yields for the different treatments are given in Table 43.

TABLE 43. COMPARISON OF AMMONIUM SULPHATE, F.Y.M. AND THEIR COMBINATION (MADHYA PRADESH)

Level of N in lb./acre	Yield of paddy in lb. per acre		
	Ammonium sulphate	Farmyard manure	½ Ammonium sulphate +½ F.Y.M.
10	1,076	875	1,060
20	1,323	1,017	1,215
Control yield	648 lb.		

In this case also, the response to the application of ammonium sulphate over the basal dressing of farmyard manure is not superior to the application of ammonium sulphate alone.

Two series of experiments with F.Y.M., ammonium sulphate and their combinations on an equal nitrogen basis were conducted at Kudwani in Kashmir. In one series from 1941-42 to 1947-48, the levels of 30 and 45 lb. N per acre, and in the other series from 1944-45 to 1947-48, the levels of 75 and 90 lb. N per acre, were tried. The average yields for the two series are given in Table 44.

TABLE 44. COMPARISON OF AMMONIUM SULPHATE, F.Y.M. AND THEIR COMBINATION (KUDWANI—KASHMIR)

Level of N in lb. per acre	Yield of paddy in lb. per acre			
	F.Y.M.	Ammonium sulphate	F.Y.M.+ Ammonium sulphate	Control
	Series A. (*average of* 1941-42 *to* 1947-48)			
30	1,739 (5.67)	2,218 (21.63)	2,098 (17.63)	1,569
45	1,827 (5.67)	2,537 (21.51)	2,537 (21.58)	
Mean	1,781	2,378	2 171	
	Series B. (*average of* 1944-45 *to* 1947-48)			
75	1,881 (3.41)	2,209 (7.78)	2,008 (5.11)	1,625
90	1,991 (4.07)	2,421 (8.85)	2,209 (6.49)	
Mean	1,936	2,315	2,108	

Note: Figures in brackets give the response in pounds of paddy per acre per lb. of N.

It will be seen that the application of heavy doses of either F.Y.M. or ammonium sulphate gives smaller response, and the combination of the two is not superior to ammonium sulphate alone.

Ammonium Sulphate with Green Manures. Experiments with a combination of ammonium sulphate and green manures conducted at Pattambi showed that the response to ammonium sulphate over a basal dressing of green leaf was not so remarkable in the first crop as it was in the second crop. The average yields are given in Table 45.

At the Central Rice Research Institute, green manuring with *dhaincha* has been found to be even better than ammonium sulphate at the same level of nitrogen (Nair, 1953). An increase in yield was obtained up to 20 lb. of N as green manure

or 30 lb. N as ammonium sulphate or a combination of the two. The average yields obtained for five years are given in Table 46.

TABLE 45. EFFECT OF VARYING DOSES OF N AS AMMONIUM SULPHATE OVER BASAL DRESSING OF GREEN LEAF (PATTAMBI)

Basal dressing of green leaf in lb. per acre	Average yield of paddy in lb. per acre (1945-46) — Level of N in lb. as ammonium sulphate		
	0	15	30
1st crop			
0	2,040	2,370	2,470
4,000	2,250	2,530	2,390
2nd crop			
0	2,010	2,150	2,550
4,000	2,060	2,410	2,620

TABLE 46. EFFECT OF VARYING DOSES OF NITROGEN AS AMMONIUM SULPHATE AND GREEN MANURE (AVERAGE FOR 5 YEARS)

Ammonium sulphate lb. N/A	Yield of paddy in lb. per acre — Green manure—lb. N/A				Mean
	0	10	20	30	
0	2,170	2,607	2,822	2,879	2,619
10	2,323	2,711	2,779	2,961	2,693
20	2,590	2,906	2,948	2,958	2,850
30	2,832	2,883	3,036	2,957	2,925
Mean	2,479	2,777	2,896	2,937	—

It will be seen from the results that green manure is more efficient than ammonium sulphate, and the response with 20 lb. N as green manure is similar to that of 30 lb. N as ammonium sulphate.

Phosphate with Green Manure. The application of phosphatic fertilizers to the green manure crop is recommended. This, apart from adding the much-needed fertilizer to the soil, increases the yield of green matter, and thus supplies increased nitrogen when the crop is ploughed in before the planting of paddy. In an experiment at Gaya (Bihar) during 1936-37 to find out the effect of application of green manure and farmyard manure with or without additional phosphates, the effect of application of P_2O_5 to the green manure was the most pronounced.

At Ranchi, in an experiment conducted for five years (1930-35) to study the effect of phosphatic fertilizers on paddy, singly or in combination with green manure,

it was found that the effect of phosphatic manures increased when applied in conjunction with green manure.

At Berhampur (Orissa), in an experiment conducted for four years (1933-37) to compare application of *dhaincha* at 4,000 lb. per acre alone and in combination with 40 lb. P_2O_5 as bonemeal and superphosphate, the latter gave a significantly higher yield than either *dhaincha* alone or *dhaincha* in combination with bonemeal. The residual effect of these treatments was also significant in the same order.

Several experiments conducted in Madras State showed that except at Coimbatore and Pattukkottai, there was no additional response with phosphate when applied in conjunction with green manure. In some places, negative results were also reported by the use of phosphate in combination with green manures. At Aduthurai (Madras) and Samalkota (Andhra Pradesh), it has been reported that the addition of bonemeal to green manure was not found necessary. At Palur, the addition of bonemeal as a basal dressing to *dhaincha* showed no effect, and even showed a tendency to depress the yield.

These results show that response to phosphate application in conjunction with green manure varies considerably, and is more pronounced in locations where the phosphate application generally gives a response.

RESIDUAL EFFECT OF INORGANIC FERTILIZERS AND GREEN MANURES

A large number of experiments conducted to determine the residual effect of ammonium sulphate and other nitrogenous inorganic fertilizers indicate that none of these leaves any residual effect in the soil. There is lack of evidence to prove the extent of the residual effect of green manuring. Joachim (1931) states that under tropical conditions, the effect of green manuring may be expected to last only for six months so far as nitrogen is concerned. At the Chinsurah Farm (West Bengal), experiments indicated that there is no residual effect by green manuring or by the application of inorganic nitrogenous fertilizers. In Nagina (Uttar Pradesh), where observations of residual effect were made after five years of continuous application of ammonium sulphate, sannhemp as green manure and superphosphate, no residual effect was found with ammonium sulphate, but green manure and superphosphate gave some residual effect as can be seen from Table 47.

TABLE 47. RESIDUAL EFFECT OF GREEN MANURING AND INORGANIC FERTILIZERS (NAGINA—UTTAR PRADESH)

Treatments	Yield of paddy in lb. per acre			
	No manure (control)	Sulphate of ammonia	Sannhemp	Superphosphate
Mean yield during 1933-38	2,141	2,758	3,390	3,282
Residual effect (1938-39)	1,629	1,703	1,913	2,045

From the available data, it may be inferred that ammonium sulphate leaves practically no residual effect, while the green manure and phosphate may leave some small residual effect in certain places.

Experiments to determine the cumulative effect of a continuous application of inorganic and organic nitrogenous fertilizers over a long period are under way.

CULTURAL PRACTICES

The cultural practices adopted for rice production in the different States vary considerably, depending upon the soil, climate, irrigation facilities and the system of cropping. Investigations on various practices like dry ploughing, direct sowing, transplanting, optimum seed-rate, time of planting, spacing and age of seedlings have received considerable attention, and the work has been reviewed by Pillai (in press). In recent years, experiments with double cropping, sequence of cropping with rice and control of weeds by use of selective herbicides have also been carried out.

Preparatory Cultivation. Investigation on the ploughing of the field either in winter or summer was carried out in Madras, Andhra Pradesh, Uttar Pradesh, Orissa and Assam. In Madras and Andhra Pradesh, the heavy clay soils of the Cauvery, Godavari and Krishna deltas growing wet rice are not generally opened. They remain fallow during the summer, and get very hard and crack deeply. The preparation of the land commences only after letting in water at the time of puddling. Experiments conducted in Madras State showed that summer ploughing of such heavy soils was harmful, and caused a 10 to 15 per cent. reduction in yield of the succeeding rice crop, while the ploughing of light soils was not harmful. Trials conducted at Nagina in Uttar Pradesh, however, on heavy alluvial soils have indicated that the summer ploughing was distinctly beneficial to the rice crop, giving an increase of 14 to 30 per cent. in yield. Work at the Central Rice Research Institute has shown that the summer ploughing of fairly heavy silty loam was not harmful to the rice crop.

With regard to depth and number of ploughings, some experiments were conducted in Madras and Assam. In both the places, it was found that ploughing six inches deep with mould board plough as compared to ploughing two to three inches deep with the *desi* plough gave a yield-increase of 10 to 15 per cent. It is, however, recommended in Assam that deep ploughing should be done only once in three or four years. As to the number of ploughings, a trial conducted at Aduthurai in Madras State has indicated that eight ploughings with the country plough at suitable intervals gave the best yield, and four ploughings with the iron plough at the appropriate time were as good as the former.

The comparative efficiency of different types of ploughs and puddling implements has not been studied in a systematic manner. However, observations on the working of these implements indicate that among the different types of wooden ploughs, the Orissa 'duck foot' plough is more efficient than the rest for puddling operations. For the initial opening of the wet land, any iron mould board plough like 'Cooper 11' is efficient. Implements like the 'wet land puddler' and 'Burmese satoon' were found economical and useful for creating a good puddle, and also for burying the green manure crops after the land had been opened with the iron plough.

Investigations on the mechanization of rice cultivation with a Ferguson tractor are in progress at the Central Rice Research Institute to study the econo-

mics and utility of the tractor in rice-farming and the effect of tractor-puddling on the yield of the rice crop.

Seeding. Experiments on broadcast sowing *versus* transplanting conducted in almost all the States have clearly indicated that transplanting was better than broadcasting by 10 to 25 per cent., but in the low land of Assam, broadcasting was found superior, as the transplanted crop was usually affected by floods before it could establish itself.

Trials with dibbling sprouted seed in a wet puddle conducted in Madras and at the Central Rice Research Institute have shown that this practice is as good as transplanting. The yield data are given in Table 48.

TABLE 48. COMPARISON OF TRANSPLANTING AND DIBBLING OF RICE CROP

	Yield of paddy in lb. per acre (Average of 2 years 1948-50)	
	Transplanting	Dibbling
Rice Research Station, Ambasamudram (Madras)	2,884	2,919
Rice Research Station, Tirurkuppam (Madras)	2,460	2,404
Central Rice Research Institute, Cuttack (Orissa)	3,026	2,939

Experiments on the different methods of direct sowing, *viz.*, broadcasting and dibbling, conducted in Madras, Madhya Pradesh and Orissa have shown that dibbling is superior to broadcasting from the yield point of view.

Seed-rate. Experiments on the seed-rate for broadcast-sowing, conducted in Madras, Uttar Pradesh, Hyderabad, Assam, Orissa and Madhya Pradesh, have indicated that 80 lb. per acre was the optimum. This seed-rate could, however, be reduced to 60 lb., if the soil and moisture conditions at the time of sowing were ideal.

Experiments to determine the optimum seed-rate for the nursery were conducted in various States and the results indicate that the optimum seed-rate for the nursery is 400 lb. per acre for coarse varieties, and 300 lb. for fine varieties. With this seed-rate, an acre of the nursery will provide seedlings to transplant 10 to 12 acres.

Manuring of Nursery. With regard to the manuring of the nursery, experiments carried out in Madras, Uttar Pradesh, Andhra Pradesh, Orissa and Bihar with varying doses of fertilizers, as for instance 0, 100, 200 lb. of nitrogen per acre at Nagina (Uttar Pradesh), indicate that heavy manuring of the seed-bed does not increase the yield of the transplanted crop to any appreciable extent. Similar results were obtained in an experiment conducted at the Central Rice Research Institute with seedlings from heavily manured (150 lb. N, 100 lb. P_2O_5 per acre) and normally manured (20 lb. N, 16 lb. P_2O_5 per acre) nurseries. The yield data are given in Table 49.

TABLE 49. YIELD DATA OF NURSERY MANURING WITH VARYING DOSES OF FERTILIZERS

Varieties	Treatment	Yield of paddy in lb. per acre (Average of 2 years)
T. 1242	Heavily manured seedlings	2,653
	Normally manured seedlings	2,716
BAM. 9	Heavily manured seedlings	3,123
	Normally manured seedlings	3,136

Age of Seedling. Experiments on the age of seedlings, ranging from 3 to 11 weeks, were conducted in Bengal, Madras, Andhra Pradesh, Bihar and Orissa. The results of the trials indicated that the yield of a variety was influenced to some extent by the age of the seedling, and that the optimum age varied from variety to variety. However, the general trend of the trials in all the States indicated that the optimum age of seedlings for planting was three to four weeks for short-duration varieties and five to six weeks for long-duration varieties.

Optimum Spacing and Number of Seedlings per Hill. Spacing has a considerable influence on the tillering of the plant and the yield of the crop. However, the spacing will depend on the duration of the variety, time of planting and the fertility of the soil. The number of seedlings per hill is closely associated with spacing.

In Madras State, the results of experiments at various stations indicate that for a long-duration variety, the planting of two seedlings per hill at a distance of 6 × 12 inches, and for a short-duration variety, 4 × 4 inches or 6 × 6 inches is optimum. Giving a wide spacing to short rices and a narrow spacing to long duration varieties adversely affect the yield of the crop. The yield data of an experiment conducted at the Rice Research Station, Ambasamudram in Madras State, is given in Table 50.

TABLE 50. YIELD DATA OF EXPERIMENT CONDUCTED AT AMBASAMUDRAM

	Short-duration crop Spacing				Long-duration crop Spacing			
	4×4 inches	6×6 inches	6×12 inches	12×12 inches	4×4 inches	6×6 inches	6×12 inches	12×12 inches
Acre-yield in lb. (Average of 3 years)	3,691	3,437	3,030	2,865	2,607	2,744	2,831	2,768
Percentage on control (6×6 inches)	107.4	100.0	88.2	83.4	95.0	100.0	103.2	100.8

In Bengal, planting at 6 × 6 inches with two seedlings gave a significantly higher yield than planting at 9 × 12 inches. In Ratnagiri (Bombay State), however, the planting of eight seedlings per hill at 10 × 10 inches has been found to be the optimum. In Assam, the spacing of 6 × 9 inches, with four seedlings per hill, was found to be optimum both for the *boro* and *sali* rices. Experiments carried out

at the Central Rice Research Institute indicate that the planting of two to three seedlings at a spacing of 6 × 6 inches for early varieties, and 9 × 9 inches for late varieties is the optimum. Pillai (in press) has observed that the spacing will vary from place to place according to the soil conditions and variety grown, while the season seems to have no influence on the spacing.

From available experimental results, it may be concluded that too wide a spacing affects the yield adversely, owing to the reduction in the total number of ear-bearing tillers per acre, and to the uneven ripening and late tillers producing immature grains. Though with a wider spacing, large ears and more tillers per plant are produced, they do not compensate for the reduction in population density in a unit area.

Optimum Time of Planting. The time of planting has a marked influence on the yield of the crop, and other agronomic practices like spacing and number of seedlings have to be modified according to the time of planting. It has been generally found that planting early in the season is always conducive to higher yields. However, in rain-fed areas, the time of planting is determined by the outbreak of the monsoons. When the monsoon is delayed, the planting also gets delayed, and with a few exceptions, most varieties suffer in yield to a large degree. The optimum time of planting varies from place to place, depending upon the environmental factors. From experimental results, it has been found that in the eastern zone comprising Assam, Orissa, West Bengal and Bihar, the optimum period of transplanting is the month of July. Planting delayed beyond the middle of August gives a poor crop, yielding only about 50 per cent. of the normal yield. In Titabar (Assam), the yields of the rice crop obtained with the different plantings are given below.

Date of planting	Average yield of paddy in lb. per acre (1939-40)
July 5	3,084
July 25	2,926
August 15	2,644
September 5	1,654

For *boro* paddy in Assam, the last week of December has proved to be the best period for planting. In the northern zone comprising Uttar Pradesh, the Punjab, and Kashmir, transplanting in the first week of June has proved to be the best. The results of complex cultural experiments at Nagina (Uttar Pradesh) showed that the planting in the first week of June gave the highest yield, while planting in the first week of July gave 20 per cent. reduction in yield, and planting in August gave less than half the yield of the July planting. Similar results were also obtained in the experiments conducted in Kashmir State.

For the delta areas of the Cauvery, Vaigai and Tambraparani in South India, the best period of planting the second crop is from the second to the third week of October, beyond which yield is adversely affected. The yield data of an

experiment conducted with the second crop at the Rice Research Station, Ambasamudram (Madras) are given below.

Date of planting (Variety: CO. 8)	Yield of paddy in lb. per acre (Average of 3 years)
October 10	2,321
October 20	2,258
October 30	2,101
November 10	1,796
November 15	1,556

Similar results were obtained at the Rice Research Station, Pattambi.

For the areas comprising the deltas of the rivers Godavari and Krishna in Andhra Pradesh the best period for planting the second crop is from the last week of January to the first week of February. Results of trials conducted with the second crop at the Maruteru Rice Research Station indicated that the early planted crop in December succumbed to the attack of the stem borer, while the late planted crop escaped this attack and gave better yields.

Double Cropping of Rice. In south India, where irrigation facilities exist, two crops of rice are taken during the year in the same wet land. A short- or medium-duration variety of rice followed by a long-duration variety is grown in Madras State, while a medium- or long-duration variety, followed by a short- or medium-duration variety, is raised in Andhra Pradesh. The sequence in which the varieties of different durations are taken is determined by the prevailing seasonal conditions in the respective areas. In the rice tracts of Orissa, West Bengal, Assam, Bihar and Uttar Pradesh, only a single crop of rice is grown in the *kharif* season, followed by a *rabi* crop of *mung*, gram or other pulses. Even where irrigation facilities exist, double cropping of rice is not commonly practised.

Investigations at the Central Rice Research Institute have shown that two crops of rice can be successfully grown in Orissa, the first crop from June to December, and the second crop of a short-duration variety from January to April. The nursery for the second crop is raised during December, and the crop is planted during January. It has been found that for the second crop, varieties like *PTB. 10*, *Mtu. 9* and *Mtu. 15* are suitable, and yield about 2,000 lb. of rice in husk per acre. The second crop is often attacked by the stem borer, but the timely spraying of the crop with Folidol effectively controls the pest.

Trials conducted at the Nagina Rice Research Station in Uttar Pradesh have shown that it is possible to take two crops of rice during the year by an adjustment of the time of sowing. A short-duration variety (*T. 22*) is sown broadcast in well-prepared land in the first or second week of April, and is irrigated as and when necessary. This crop is harvested in the third week of July, and the land is immediately puddled and planted with a variety like *T. 100*, which can be harvested by the first week of December. This system of double cropping of rice gives an additional production of about 1,400 lb. of rice in husk per acre.

Sequence of Cropping with Rice. As stated earlier, in wet land rice cultivation in India, no systematic rotation is possible due to the inadequate control of irrigation and drainage. Therefore, the growing of the rice crop in the same land year after year is inevitable. However, a well-planned sequence of cropping can be practised, with rice in the main season followed by a legume or a cash crop as a subsidiary crop in the dry season, for maintaining soil fertility and securing better economic returns. Where no irrigation facilities are available, only a quick-growing legume which matures in residuary soil moisture is cultivated. With irrigation facilities, however, different crops can be grown. Vachhani (1955) has reported the results of an experiment conducted at the Central Rice Research Institute to investigate the possibilities of growing various crops in sequence with rice and to study their effect on the yield of the succeeding rice crop. Eight different crops besides *dalua* rice (with and without green manure) were grown during the winter season followed by a short-duration rice crop during the main season. The winter crops were given a basal dressing of two and a half tons of cattle manure and 100 lb. of superphosphate per acre, while no fertilizer was supplied to the main season rice crop. Irrigation was available up to April-May, and the number of irrigations varied with the different crops.

The results obtained are given in Table 51.

TABLE 51. YIELD OF PADDY AND DIFFERENT SINGLE SEASON ROTATION CROPS (AVERAGE OF TWO YEARS)

Rotational treatments		Preceding subsidiary crop yield in lb. per acre	Succeeding main rice crop	
Preceding subsidiary crop (Nov.-May)	Succeeding main crop (June-Oct.)		Yield of paddy in lb. per acre	Percentage
Fallow	Rice (control)	—	2,848	100.0
Rice	Rice	1,695	2,550	89.5
Rice (green manured with *Dhaincha*)	Rice	2,134	2,530	88.8
Rice (green manured with *Mung*)	Rice	2,264	2,889	101.4
Mung for Seed + *Pillipesara*	Rice	366	3,092	108.6
Mung	Rice	325	2,933	103.0
Gram	Rice	962	2,863	100.5
Groundnut	Rice	1,371	3,085	108.3
Cotton	Rice	1,081*	2,581	90.6
Wheat	Rice	476	2,816	98.9
Linseed	Rice	374	2,760	96.9
Mustard	Rice	144	2,963	104.0
C.D. (0.05) per acre			143	

* Yield of seed cotton.

It will be seen from Table 51 that the inclusion of a leguminous crop in sequence with rice has a beneficial effect on the succeeding rice crop. The growing of *mung* plus *pillipesara* and groundnut has the maximum beneficial effect on the succeeding rice crop. The effect of different rotational treatments is discussed below.

1. *Rice—Green Manuring—Rice*: The growing of a green manuring crop, particularly the quick-growing *mung*, after the harvest of the main season crop and ploughing it into the soil at the time of preparation of land for *dalua* rice, improves the fertility of the soil, and increases the yield of rice as seen from Table 52.

TABLE 52. YIELD OF DOUBLE CROPPING OF RICE WITH GREEN MANURE

Treatment	Subsidiary rice in lb. per acre	Main season rice in lb. per acre	Total yield per year in lb. per acre
Fallow — Rice	—	2,848	2,848
Rice — Rice	1,695	2,550	4,245
Rice (green manured with *dhaincha*) — Rice	2,134	2,530	4,664
Rice (green manured with *mung*) — Rice	2,264	2,889	5,153

Thus, with the proper sequence of cropping, a total yield of over 5,000 lb. of paddy can be obtained during the year in areas where irrigation is available.

2. *Legume-Rice*: The choice of a legume for sowing in sequence with rice depends upon the soil and moisture conditions. Where the soil condition is favourable and the land is free from the rice crop early in the season, the growing of gram (*Cicer arietinum*) is profitable. The growing of a mixture of *mung* and *pillipesara*, where the former is left for seed and the latter buried as green manure, appears to have the maximum beneficial effect on the succeeding rice crop.

3. *Groundnut-Rice*: In this sequence, an average yield of 1,371 lb. of groundnut has been obtained. Besides, it had a beneficial effect on the succeeding rice crop, which gave an average yield of 3,085 lb. per acre, as compared to 2,848 and 2,550 lb. per acre in the fallow-rice and rice-rice rotations, respectively. In southern India also, the inclusion of groundnut in rice cropping has been found to be profitable.

Hence in southern and eastern India, where the winter temperature is not low, a crop of groundnut can be profitably included in the sequence of cropping with rice. The groundnut crop sown in December, after the harvest of the main season rice crop, will be ready for harvest by the month of May, and would require only three to four irrigations.

4. *Cotton-Rice*: A short-duration cotton variety, *P-216 F* was sown during November-December after preparing the land on the harvest of rice, and the last picking was taken by May-June. It gave an average yield of 1,081 lb. of seed cotton, and the succeeding rice crop yielded 2,581 lb. of paddy per acre. Thus, the inclusion of cotton in sequence with rice gives good economic return. In Andhra Pradesh and Madras also, the cotton variety, *P-216 F*, grown after rice crop, has been found

to be successful. Cotton is dibbled in-between the stubbles after harvest of the rice crop, and the land is intercultured when it comes to proper condition.

Inclusion of crops like wheat, linseed and mustard in sequence with rice does not appear to have any adverse effect on soil fertility, but the yields of these crops are rather low.

WEED CONTROL BY HERBICIDES

Weed infestation of the rice field considerably reduces the yield of the crop. Though the importance of weed control is well recognised by cultivators, effective methods of control are usually not adopted, and weeding, which is usually done by hand, is either ignored, or not properly done as it is arduous and time-consuming. In recent years, synthetic growth-regulating substances, which are selective in their action, are being successfully used for the control of weeds in the field for various crops.

Investigations have been carried out at the Central Rice Research Institute to determine the proper dosage and time of spraying, and to compare the efficiency of various formulations of selective herbicides for the control of weeds and their effect on the yield of the rice crop. Three formulations, *viz.* Phenoxylene-30 (M.C.P.A.), Chloroxone (2,4-D) and 2, 4, 5-T were tested at varying doses and sprayed at different stages of plant growth.

Time of Spraying: It has been reported by Vachhani and Chaudhry (1955) that spraying the rice crop with herbicides six weeks after planting appeared to be the best for the control of weeds, and did not cause any injury to the rice crop. Spraying the field before sowing affected germination, while spraying the crop later than six weeks after planting caused injury to the rice plant, and resulted in sterile earheads to the extent of 14.3 to 24.7 per cent.

Dosage: Regarding dosage, it was found that spraying the various herbicides at 2 lb. acid equivalent per acre in 100 gallons of water gave the best control of weeds, and did not cause any injury to the crop.

Formulations of Herbicides. A trial was conducted with three formulations in comparison with the customary hand weeding and no weeding. The herbicides were used on equal acid basis of 2 lb. per acre, in 100 gallons of water, sprayed six weeks after planting. The yield of paddy obtained with the various treatments was considered as an index of weed control. The yield data are given in Table 53.

TABLE 53. EFFECT OF HERBICIDE FORMULATIONS ON YIELD OF PADDY (AVERAGE OF 1953-54 TO 1955-56)

Treatment	Yield of paddy in lb. per acre	Percentage
1. Phenoxylene-30 (M.C.P.A.)	3,729	117.9
2. Hand-weeding	3,595	113.6
3. Chloroxone (2, 4-D)	3,554	112.3
4. 2, 4, 5-T	3,295	104.2
5. Control	3,164	100.0

As shown in Table 53, Phenoxylene-30 (M.C.P.A.) was found to be the most effective of all the herbicides tried, and was followed in order of merit by hand-weeding and chloroxone (2, 4-D). Spraying with 2, 4, 5-T was not effective.

As for the economics of spraying, it was found that the cost of hand weeding was almost the same as that of spraying with Phenoxylene. Therefore, this chemical can profitably be used for controlling weeds in rice fields in localities where sufficient labour for hand weeding is not available.

It was noted that the herbicides tested were effective in controlling the broad-leaved weeds. Amongst the narrow-leaved plants, cyperaceous weeds were susceptible, and were effectively controlled by spraying with M.C.P.A., while graminaceous weeds were not affected.

STUDY OF PLANT CHARACTERS

Correlation Studies. The purpose of correlation studies in general is to detect the casual relationship between any two plant characters in question. Both inter-varietal and intra-varietal correlation studies in rice have been carried out at various places. Yield being the most important of all the characters, its correlation with other attributes has received the greatest attention.

Workers on rice in different parts of the country have found different degrees of correlation between yield and other characters. All of them found a fairly high amount of correlation between yield and number of earheads per plant.

Mahalanobis (1934), studying the means of various characters of 147 rice varieties in Bengal, found that the yield was moderately correlated with the number of tillers per plant and with length of leaf, but appeared to be independent of other characters such as grain dimensions, height, duration, etc. Narasinga Rao (1937) studied the correlation between yield and some characters in different rice strains at Rice Research Station, Berhampur, and reported that the correlation of yield was highest with number of tillers, followed by number of grains per ear and panicle length. He found that the correlations of yield with the number of grains per ear and ear-length were somewhat higher under unmanured condition than under manured condition. Ramiah (1953a), summarising the results obtained at various research stations, reported that a moderate correlation existed between mean yield and number of tillers per plant, height was fairly correlated with yield and the ear-length, and the mean number of grains per ear was feebly correlated with yield.

At the Central Rice Research Institute, inter-varietal correlations between yield and number of panicles and between yield and plant height were found to be 0.52 and 0.47, respectively, in a varietal trial with 36 varieties of 90 to 110 days duration. However, the ear-length was found to be negatively correlated with the number of earheads.

Intra-varietal correlation was studied in a varietal trial with seven short-duration varieties (90 to 100 days). The total correlation coefficients between the various plant attributes were calculated for each variety and are given in Table 54.

TABLE 54. TOTAL CORRELATION COEFFICIENTS IN DIFFERENT VARIETIES
(CENTRAL RICE RESEARCH INSTITUTE)

Variety	r_{12}	r_{13}	r_{14}	r_{23}	r_{24}	r_{34}
Adt. 3	0.305 ± 0.0624	0.461 ± 0.0447	0.219 ± 0.0649	+ 0.011	0.267 ± 0.0518	0.267 ± 0.063
Adt. 4	0.498 ± 0.0497	0.469 ± 0.0511	0.079 ± 0.0678	— 0.052	0.184 ± 0.0630	0.247 ± 0.061
PLR. 2	0.359 ± 0.0595	0.450 ± 0.0516	0.290 ± 0.0615	— 0.067	0.326 ± 0.0577	0.192 ± 0.064
B. 76	0.401 ± 0.0560	0.258 ± 0.0613	0.187 ± 0.0665	— 0.044	0.301 ± 0.0580	0.233 ± 0.062
N. 136	0.358 ± 0.0585	0.478 ± 0.0517	0.242 ± 0.0494	— 0.065	0.360 ± 0.0564	0.249 ± 0.063
Dca. 14	0.334 ± 0.0579	0.219 ± 0.0621	0.340 ± 0.0611	— 0.122	0.212 ± 0.0617	0.190 ± 0.066
Plr. 7	0.449 ± 0.0550	0.633 ± 0.0396	0.158 ± 0.0669	— 0.092	0.160 ± 0.0629	0.192 ± 0.066
Average	0.386	0.402	0.216	— 0.017	0.288	0.224

It will be seen from Table 54 that marked differences in the magnitude of the correlations exist among varieties for yield and ear-length as well as the number of earheads and plant height, at harvest. The coefficients of correlation between earhead number and ear-length are very low and negative, and were not significant for any variety. The other correlation coefficients, excepting that between yield and plant-height in the case of *Adt. 4*, were significant.

The partial correlation coefficients were also calculated and are given in Table 55.

TABLE 55. PARTIAL CORRELATION COEFFICIENTS
(CENTRAL RICE RESEARCH INSTITUTE)

Variety	r12.34	r13.24	r14.23	r23.14	r24.13	r34.12
Adt. 3	0.3298	0.4785	—0.0012	—0.2192	0.3180	0.2468
Adt. 4	0.6145	0.6123	—0.2072	—0.4311	0.2843	0.3287
Plr. 2	0.3904	0.4865	0.0962	—0.3023	0.2794	0.1503
B. 76	0.4088	0.2924	—0.0022	—0.2270	0.2931	0.2478
N. 136	0.4252	0.5274	—0.0342	—0.3558	0.3665	0.2458
Dca. 14	0.3223	0.2279	0.2460	—0.2292	0.1420	0.1538
Plr. 7	0.6610	0.7578	—0.0968	—0.5629	0.1997	0.2099

It will be interesting to compare the total correlation coefficients and the corresponding partial correlations. The correlation between yield and number of earheads improved in almost all the varieties. The improvement of the relationship between yield and ear-length was observed in all cases, whereas the relationship between yield and height of plant was negligible when the influence of the other two characters was eliminated. The correlation between number of earheads and ear-length became prominent after the influence of yield and plant-height was eliminated. The correlation between earhead number and height was improved for *Adt. 3*, *Adt. 4*, *N. 136* and *Plr. 7*, and the correlation between ear-length and height was improved in the case of *Adt. 4*, *B. 76* and *Plr. 7*.

The multiple regression equations for yield on earhead number, ear-length and height at harvest, together with the multiple correlation coefficient which measures the combined importance of the three independent factors on the yield, are given in Table 56 for each variety.

The equations show that the number of earheads has the maximum influence, on plant-yield and the height the least. The plant-yield was increased by 0.5 to 0.8 gm. and 0.2 to 0.6 gm. by unit increase in the number of earheads and length of earhead, respectively. The fact that the multiple correlation (R) was not very high indicates that other characters such as grain-weight and density are important contributory factors in the estimation of varietal yields.

TABLE 56. MULTIPLE REGRESSION EQUATIONS FOR YIELD ON EARHEAD NUMBER, EAR-LENGTH AND HEIGHT

Variety	Multiple regression equations	Multiple correlation R_1 (234) of yield on number of earheads, length of earhead and height
Adt. 3	$X_1=0.5125\ X_2+0.3499\ X_3-0.0002\ X_4-3.2883$	0.5124
Adt. 4	$X_1=0.8005\ X_2+0.4186\ X_3-0.0372\ X_4-1.0910$	0.7179
Plr. 2	$X_1=0.5350\ X_2+0.5267\ X_3+0.0237\ X_4-8.7673$	0.6005
B. 76	$X_1=0.7503\ X_2+0.2645\ X_3-0.0005\ X_4-2.6161$	0.4814
N. 136	$X_1=0.6185\ X_2+0.4057\ X_3-0.0052\ X_4-4.6822$	0.6174
Dca. 14	$X_1=0.5639\ X_2+0.1776\ X_3+0.0513\ X_4-5.3735$	0.4793
Plr. 7	$X_1=0.8306\ X_2+0.6134\ X_3-0.0106\ X_4-8.6709$	0.8145

X_1=Yield per plant in gm.
X_2=Number of earheads
X_3=Ear-length in cm.
X_4=Plant height in cm.

The percentage contribution of various combinations of characters towards yield in different varieties is shown in Table 57.

TABLE 57. PERCENTAGE CONTRIBUTION OF VARIOUS COMBINATIONS OF CHARACTERS TOWARDS YIELD (CENTRAL RICE RESEARCH INSTITUTE)

Percentage contribution due to	*Adt. 3*	*Adt. 4*	*Plr. 2*	*B. 76*	*N. 136*	*Dca. 14*	*Plr. 7*
(*i*) Earhead number, ear-length and height of plant ..	26.26	51.54	36.06	23.17	38.12	22.97	66.34
(*ii*) Earhead number and ear-length	30.24	49.41	36.37	23.69	33.58	17.99	66.02
(*iii*) Earhead number and height of plant	11.37	24.77	16.20	16.59	14.30	18.75	20.95
(*iv*) Earhead length and height of plant	22.29	22.19	24.52	8.34	24.49	14.02	40.25

It will be seen from the Table that the joint contribution of all the three characters towards yield ranged from 23 to 66 per cent., whereas that of ear-length and earhead number, earhead number and height, and ear-length and height ranged from 18 to 66, 11 to 25 and 8 to 40 per cent., respectively.

The individual contributions of the different characters towards yield are given in Table 58.

It will be seen from the Tables that the contribution of height towards yield was negligible in almost all the varieties. The magnitude of contribution of the other two characters varied from variety to variety.

TABLE 58. PERCENTAGE CONTRIBUTION OF INDIVIDUAL CHARACTERS TOWARDS YIELD (CENTRAL RICE RESEARCH INSTITUTE)

Percentage contribution due to	*Adt. 3*	*Adt. 4*	*Plr. 2*	*B. 76*	*N. 136*	*Dca. 14*	*Plr. 7*
(*i*) Number of earheads ..	10.88	37.36	15.24	16.71	18.08	10.39	43.69
(*ii*) Length of earhead ..	22.90	37.49	23.67	8.55	27.82	5.19	57.43
(*iii*) Height of plant at harvest	1.44	4.29	0.93	0.0005	0.12	6.05	0.94

Discriminant Function. Improvement in yield is the chief consideration in any plant-breeding programme. For this purpose, the selection of superior genotypes has to be made on the basis of phenotypic values, which are subject to a large non-heritable variabilities of varying degrees. The efficiency of selection under such circumstances can sometimes be improved by taking into consideration simultaneously the phenotypic values of a number of plant attributes which are correlated with genotypic values of the character under consideration. The discriminant function technique developed by Fisher (1936) was applied in India for plant selection in cotton by Panse and Khargonkar (1949) and in wheat by Simlote (1947). The discriminant function technique for varietal selection in rice was studied at the Central Rice Research Institute in a varietal trial consisting of 25 varieties of medium duration (125 to 140 days) and the results have been reported by Abraham *et al.* (1954). The discriminant function formulae obtained with different characters as reported by them, are given in Table 59.

TABLE 59. DISCRIMINANT FORMULAE AND RELATIVE EFFICIENCY

Characters included	Discriminant function	Relative efficiency compared with straight slection (per cent.)
(*a*) Yield components (x_2, x_3 and x_4)	$X_1 = x_2 + 0.054\ x_3 + 0.197\ x_4$	96.80
(*b*) Yield (x_1) and yield components (x_2, x_3, and x_4)	$X_2 = x_2 + 0.075\ x_3 + 0.233\ x_4 + 3.106 x_1$	100.21
(*c*) Yield (x_1) and yield components (x_2, x_3 and x_4) and tillers at flowering (x_5)	$X_3 = x_2 + 0.084\ x_3 + 0.263\ x_4 + 0.104 x_5 + 3.984\ x_1$	100.13

x_1 = Yield per plant
x_2 = Number of ear bearing tillers
x_3 = Number of grains per acre
x_4 = Weight of thousand grains
x_5 = Total number of tillers at flowering time

They concluded that selection based on yield components was not more efficient than selection based on yield alone.

However, the results obtained with varieties of particular duration will have general validity only if the magnitudes of the genetic and environmental variances and co-variances obtained are typical of the same quantities for other groups of varieties or segregating material. Further investigations are needed to ascertain the usefulness or otherwise of discriminant function technique in selection work.

FIELD PLOT TECHNIQUE

Field experiments are the main tools by which an investigator tests the relative merits of the treatments such as varieties, manures, cultivation practices, etc. A high degree of efficiency and accuracy is aimed at in modern field experimentation. To achieve this object, a number of factors have to be borne in mind. It is well known that the accuracy of a trial is greatly influenced by the size and shape of the plots and blocks employed. For conducting breeding, varietal and yield trials, a knowledge of the limits of variation in plot-size and shape in relation to accuracy of layout is necessary as also the determination of optimum size and shape of plots that can be used.

From a breeder's point of view, a knowledge of the minimum plot-size permissible is essential, as in the initial stages the seed at his disposal is limited, and it is of utmost importance for him to know the smallest size of plots that he can safely use for the breeding trials of his material.

Uniformity Trial. Uniformity trials are conducted with a view to determining the nature and extent of fertility variation in land, and the optimum size and shape of plots and blocks for getting the maximum precision in field experiments.

The optimum size and shape of an experimental plot vary with the crop, as also with the particular locality. From the uniformity trial with rice conducted at Coimbatore, Ramiah (1932) found that very small plots adequately replicated brought down the experimental error to the required precision. From the uniformity trials at the Berhampur Rice Research Station, Narasinga Rao (1937) recommended a plot of 20 × 5 feet with six replications for rice trials. He also reported that the error was reduced by elongating the plots along the fertility gradient and by compounding the blocks at right angles to it. On the basis of the results of a number of uniformity trials in India, Mahalanobis (1940) concluded that long and narrow plots were most suitable for field experiments with rice.

The results of a uniformity trial with transplanted rice conducted at the Central Rice Research Institute during the crop-season 1948-49 are discussed below.

Effect of Plot-size and Plot-shape on Variability: The coefficients of variation (C.V.) for different size and shape of plots after arranging them into blocks of five and ten plots were studied. It was found that C.V. decreased in general with increase in plot-size in either direction, the decrease being slightly greater when the larger dimension was in west-east direction. The ten-plot blocks gave a higher C.V. than five-plot block in general. It was also noticed that although there was, in general, reduction in C.V. with increasing plot-size in either direction, this reduction was practically negligible when the plots were elongated beyond 40 feet in either direction.

The coefficients of variation for various plot shapes with a given plot size were worked out. It was found that the shape of plot did not show any appreciable and consistent effect. However, it was noticed that the plots elongated in the west-east direction showed slightly less variability due to the fact that fertility gradient was more in the west-east direction. Therefore, we may take long plots in the direction of the fertility gradient if the direction of any marked fertility gradient is already known. In other cases the choice of shape of plot can be made more to suit the convenience of particular experiment to be conducted.

It may thus be concluded that whereas size of the plot has a definite effect in reducing variability for all shapes of plots, plot shape is not of much consequence in general unless there is a marked fertility gradient in one direction.

Optimum Plot-size and Number of Replications: After allowing for the number of replications, it was found that the smallest plot, 4 × 4 feet, had the maximum efficiency, and the efficiency decreased with increased plot-size. The relative efficiency of various plot-sizes, taking the efficiency of the smallest plot-size (4 × 4 feet) as unity, is given in Table 60.

TABLE 60. RELATIVE EFFICIENCY OF VARIOUS PLOT-SIZES (EFFICIENCY OF SMALLEST PLOT-SIZE AS UNITY)

Units across (N-S)	Units along (W-E)						
	1	2	3	5	6	10	15
1	1.00	0.79	0.36	.58	0.53	0.45	0.34
2	0.60	0.54	0.48	.50	0.34	0.30	0.22
3	0.53	0.41	0.38	0.35	0.30	0.28	0.18
5	0.44	0.36	0.36	—	0.09	—	—
6	0.43	0.33	0.19	0.17	0.16	0.11	0.09
10	0.32	0.28	0.14	—	0.06	—	—
15	0.26	0.22	0.09	—	0.04	—	—

It will be seen from the table that the smallest plot-size of 4 × 4 feet had the maximum efficiency. Narasinga Rao (1937) also reported that the smallest plot-size used by him (5 × 5 ft.) had the maximum efficiency.

In field experiments, investigators are not usually interested in difference of less than about 10 per cent. between the treatment means. Hence the minimum number of replications required to give a standard error of 3 per cent. of the mean was calculated for some selected plot-sizes with 5 and 10 plots per block to detect at 5 per cent. level of significance, a difference of about 10 per cent. between the treatment means with 80 per cent. probability is given in Table 61.

It will be seen from the Table that the number of replications required for a given level of accuracy and given number of plots per block, decreased with increased plot-size.

TABLE 61. MINIMUM NUMBER OF REPLICATIONS REQUIRED WITH DIFFERENT PLOT-SIZES

Plot-size in acre	Number of replications	
	5-plot blocks	10-plot blocks
1/2722.5	12	12
1/907.5	6	7
1/544.5	5	6
1/272.9	4	5
1/136.1	3	4
1/60.5	3	4

As already seen from Table 60 the efficiency is highest with the smallest plot-size and so with a given experimental area and given number of treatments, the aim should be to decrease the plot-size as far as practicable and increase the number of replications proportionately. However, there are some practical difficulties with small plots. It is also important to note that with increased number of replications and decreased plot-size, the cost of experimentation will be more than with decreased number of replications and increased plot-size. So taking into consideration the cost and agricultural conveniences, a plot-size ranging from 60 to 100 sq. ft. (1/726 to 1/436 acre) for varietal trial and 300 to 500 sq. ft. (1/145 to 1/87 acre) for manurial trial has been found suitable.

It will be seen from Table 61 that the minimum number of replications required for the plot-sizes, 60 to 100 sq. ft. and 300 to 500 sq. ft. ranged from 5 to 8 and 3 to 4, respectively. However, in actual field experiments it has been found that the C.V. is about 50 to 100 per cent. more than in the uniformity trial as could be expected due to the multiple treatments. Therefore, in actual practice, the number of replications has to be increased accordingly.

Block Efficiency: The shape of the block did not show any consistent effect on block efficiency, and it may be ordinarily decided on the basis of practical convenience. The coefficient of variation (C.V.) decreased with increased block efficiency for plots of the same size and shape. The relation between the two could be described by an equation of the form $Y=10^{a}x^{g}$, where x stands for the block efficiency and Y the corresponding C.V. A more important aspect is to find out the change in C.V. with increase in the number of plots per block with a given size and shape of plot. This relation was also found to be fairly well described by an equation of the form $Y=10^{a}x^{g}$, where Y is the C.V., and x is the number of plots per block.

Efficiency of Various Designs: The data on uniformity trial were utilized to find out the efficiencies of the Latin square and some incomplete block designs, as compared to the randomised block. The Latin square was found to be more efficient than randomised block layouts when rows or columns of the Latin square were treated as blocks. The results obtained are given in Table 62.

TABLE 62. RELATIVE EFFICIENCY OF THE LATIN SQUARE DESIGN

Plot-size (dimensions in feet)	Layout Latin square	Efficiency of Latin square against randomised block	
		When row variation alone is removed	When column variation alone is removed
8 × 8	4 × 4	1.52	1.23
12 × 12	4 × 4	1.43	1.83
8 × 8	6 × 6	1.36	1.40
12 × 12	8 × 8	1.38	1.78

The efficiencies of some incomplete block designs compared with corresponding randomised block layouts were worked out, and are given in Table 63. The efficiency of corresponding randomised block layouts is taken as 100.

TABLE 63. RELATIVE EFFICIENCIES OF VARIOUS INCOMPLETE BLOCK DESIGNS

Plot-size (dimensions in feet)	Layout		Relative efficiency per cent.
4 × 12	8 × 8	Double Lattice	95.4
4 × 12	8 × 8	Balanced lattice	103.8
4 × 12	4 × 4 × 4	Cubic lattice	89.7
8 × 8	6 × 6	Double lattice	94.4
8 × 8	6 × 6	Triple lattice	99.9
16 × 8	6 × 6	Double lattice	109.4
16 × 8	6 × 6	Triple lattice	115.9
8 × 8	4 × 4	Double lattice	91.7
8 × 8	4 × 4	Triple lattice	98.7
12 × 12	4 × 4	Double lattice	78.0
12 × 12	4 × 4	Triple lattice	84.6

It is seen from the above Table that, in general, the use of lattice designs does not bring about any gain in accuracy.

A number of field experiments were conducted at the Central Rice Research Institute with incomplete block designs. The comparative efficiencies of these designs with and without recovery of inter-block information are given in Table 64.

TABLE 64. COMPARATIVE EFFICIENCY OF INCOMPLETE BLOCK-DESIGNS WITH AND WITHOUT RECOVERY OF INTER-BLOCK INFORMATION

Layout	Plot-size in acre	No. of varieties	Efficiency of incomplete block-designs	
			With recovery of inter-block information (Per cent.)	Without recovery of inter-block information (Per cent.)
6 × 6 Double lattice in 4 replications	1/254.7	36	121	110
8 × 8 Double lattice in 4 replications	1/605	64	100	81.8
10 × 10 Triple lattice in 3 replications	1/1075	100	100	88.0
5 × 5 Quadruple lattice in 3 replications	1/395.1	25	101.7	87.6
7 × 7 Quadruple lattice in 4 replications	1/387.2	49	100.1	86.1
5 × 5 Balanced lattice in 4 replications	1/460.9	25	100	83.3
5 × 5 × 5 Cubic lattice in 3 replications	1/1489	125	100.5	72.7

These results show that even with 125 varieties, incomplete block designs are not better than randomised blocks even with recovery of inter-block information.

Progeny Row and Compact Family Block Layouts. Replicated progeny row and compact family block layouts developed by Hutchinson and Panse (1937) in connection with cotton-breeding can also be adopted for selection work in rice crop. These trials are conducted with a view to estimating the genetic variability present in the unselected bulk, and to make selections of superior progenies, if such variability exists to an appreciable extent. For estimating the genetic variability, about 100 to 150 progenies of single plants taken at random should be grown in a randomised block layout with single row plots of 25 plants, and replicated six to eight times. Observations made by Abraham *et al.* (1956) with 100 to 150 progenies revealed that the coefficients of variability ranged from 20 to 22 per cent. On the basis of this value and the usual amount of genetic variability expected in natural populations, they concluded that the number of replications to estimate the genetic variability component need not be more than about six. With such layout, genetic variability of the order of about 10 per cent. or more will be detected. Although with a self-fertilized crop like rice, there is less chance of improvement by secondary selection, recent work at the Central Rice Research Institute (Ghose and Daiya, 1952) has shown that even in this case it is possible sometimes to make improvements by secondary selection.

Results at the Central Rice Research Institute have shown that 10 to 12 families, each with 12 to 15 progenies, replicated six times, can be tested in a compact family block design with sufficient accuracy.

SAMPLING TECHNIQUE

Sampling for Yield, Tillers and Height. In the rice crop, plant attributes such as tillers, height, etc., are frequently estimated by sampling. Although yield is generally obtained by a complete harvest, sometimes sampling is also used for estimating plot-yields. The determination of suitable sampling unit, method of sampling and amount of sampling is important in a sampling programme. Investigations to determine the most efficient sampling technique for recording the growth and yield of rice, carried out by Kalamkar *et al.* (1943), showed that a positive intra-class correlation existed between adjacent bunches. They recommended a sampling unit of the following shape to be tried in future.

$$\mathrm{O} \quad \frac{\mathrm{XXX}}{\mathrm{Omit}} \quad \mathrm{O} \quad \frac{\mathrm{XXX}}{\mathrm{Omit}} \quad \mathrm{O} \quad \frac{\mathrm{XX}}{\mathrm{O\ it}}$$

$$\frac{\mathrm{XX}}{\mathrm{Omit}} \quad \mathrm{O} \quad \frac{\mathrm{XXX}}{\mathrm{Omit}} \quad \mathrm{O} \quad \frac{\mathrm{XXX}}{\mathrm{Omit}} \quad \mathrm{O}$$

This sampling unit was tried along with seven other sampling units by Sreenivasan (1950) for the estimation of rice yield, and he found this suggested structure to be the best among those tried.

Investigations were carried out at the Central Rice Research Institute on sampling technique for estimating yield and other plant attributes. The results of the investigations as reported by Abraham and Mohanty (1955) are given below.

The results showed that for estimating yield, number of earheads and number of tillers, square units, which are more convenient for recording observations, were not appreciably different from other sampling structures tried, including the one recommended by Kalamkar *et al.* (1943). Taking into consideration the cost incurred at different stages of sampling, the optimal size of sample units was found as 4 × 4 ft., 3 × 3 ft., 2 × 2 ft., and four corner plants of a 2 × 2 ft. square for yield, number of earheads, tillers and height respectively.

Table 65 gives the minimum number of samples necessary for estimating the mean values with different levels of accuracy. For this purpose, sampling structures of 3 × 3 ft. for yield and earhead number, 2 × 2 ft. for tillers and the four-corner plants of a 2 × 2 ft. unit for height has been used.

TABLE 65. MINIMUM NUMBER OF SAMPLES FOR ESTIMATING THE MEAN VALUES

No. of replications	Yield	No. of panicles	Tiller	Height
	S.E. per cent.	S.E. per cent.	S.E. Per cent.	S.E. per cent.
	4 5 6 7 8	3 4 5	3 4 5	2 3 4 5
4	1 1 5 3 2	4 2 1	8 3 2	4 2 1 1
6	5 3 2 2 1	2 1 1	4 2 1	2 1 1 1
8	4 2 2 1 1	2 1 1	2 1 1	2 1 1 1

It will be seen from Table 65 that with usual number of replications and about four samples per plot, the mean values for all characters are estimated with standard error (S.E.), not exceeding 5 per cent. In the case of height, which is the least variable character, the S.E. of the mean is even less than 2 per cent. Thus with the amount of sampling and type of sampling unit indicated above, treatment differences of the order of 12 to 15 per cent. for tiller, earhead number and yield, and four to six per cent. for height, can be detected.

Sampling for Pest and Disease Incidence. *Gall Fly and Stem Borer*: The data from different experiments at the Central Rice Research Institute, in which sampling observations were taken on these pests, were utilised to find out the efficiency of sampling and number of samples per plot necessary for estimating the incidence of these pests at the desired level of accuracy. The sampling unit adopted in these experiments was 2 × 2 feet. It was found that as far as gall fly incidence was concerned, the amount of information obtained with sampling fractions ranging from 4 to 7 per cent. varied from 50 to 65 per cent. and the S.E. with four replications was about 4 to 6 per cent. With plot-sizes ranging from 200 to 300 sq. ft. and with eight to ten plots per block, about two samples per plot were sufficient to estimate the mean values, with about 6 per cent. S.E. The number of samples necessary for a given level of accuracy was higher for the stem-borer than for the gall fly.

Blast Disease: The data on the blast incidence from five experiments at the Central Rice Research Institute were utilised to find out the efficiency of sampling, and the number of samples required to estimate the mean incidence at the desired level of accuracy. Jha (1957) reported that more than 60 per cent. of the information was recovered with sampling fractions of 8 to 14 per cent. and the standard errors obtained with 6 to 12 replications were about 3 to 6 per cent. Stratification of plots did not bring about any appreciable increase in the amount of information. With plot-sizes ranging from 150 to 400 sq. ft., and with 6 to 10 replications, about two to five samples of 2 × 2 ft. were found sufficient to estimate the mean incidence with 6 to 8 per cent. standard error.

CHAPTER 15

NITROGEN AND PHOSPHATE IN WATER-LOGGED SOILS

Rice soils during the growing season are usually submerged, as the successful cultivation of rice depends on abundant supply of water. This water-logged condition, particularly under low land rice cultivation, brings about marked changes in the soil, and the predominating condition in the rice soil is different from that of arable soils. Water-logging brings about a depletion of oxygen, and as a result the course of decomposition of organic residues in the soil is mostly anaerobic, and the nitrogen end-product of such a decomposition is largely ammoniacal nitrogen. The problem of nitrogen changes and nitrogen-recuperation in rice soils has received attention in the country, and investigations mostly relating to the fixation of nitrogen in the rice soils by blue green algae, bacterial fixation of nitrogen by *Azotobacter*, losses of nitrogen from applied manures and fertilizers, and decomposition of green manures under wet soil state have been conducted.

NITROGEN-FIXATION BY BLUE GREEN ALGAE

Nitrogen-fixation by blue green algae in rice soils has received special attention from De and his associates from Bengal. De (1936), reporting on the nitrogen supply to rice, observed that the fixation of nitrogen in water-logged soils was an algal process. De (1939) further showed that algae were the main agents responsible for nitrogen-fixation in rice soils and that bacteria had no part in it. The algae reported responsible for nitrogen-fixation were *Anabaena variabilis, A. gelatinosa* and *A. naviculoides*. Chaudhuri (1940), however, was of the view that nitrogen-fixation in the rice soils of Bengal was indirect, and the *Azotobacter* associated with the algae were primarily responsible for the fixation of nitrogen.

Singh (1942) conducted a series of laboratory studies on nitrogen-fixation in the rice soils of Uttar Pradesh and Bihar, and suggested that nitrogen-recuperation in these soils was brought about by the blue green algae, and that these bodies obtained both their carbon and nitrogen supplies from the atmospheric air. Sulaiman (1944), working on the effect of algal growth on the activity of *Azotobacter* in rice soils, observed that the number of *Azotobacter* in a water-logged soil was considerably less when algae were present, than when they were absent. He suggested that algae produced some material toxic to the growth of *Azotobacter*. De and Sulaiman (1950b) have made further observations on the fixation of nitrogen in rice soils by algae, as influenced by the presence of the crop and inorganic substances, and also on the effect of algal growth in rice-fields on the yield of the crop. The authors reported that the fixation of nitrogen by blue green algae was greater in the presence of the crop than when it was absent, and that the increase was much greater when the soil was treated with a non-nitrogenous inorganic mixture. The addition of phosphates, both in soluble and insoluble form, also stimulated the fixation of nitrogen by algae.

Information on the amount of nitrogen fixed by blue green algae under rice conditions is available from pot experiments conducted by De and Sulaiman (1950a) for five successive years. These workers followed the growth of rice in pots with and without algal growth, and observed a gain of 30 to 40 ppm of nitrogen in the pots with algal growth. They also found that the yield of the crop after the second year's trial progressively increased in the soils with algal growth, and decreased in those with no algae. Nitrogen-fixation by blue green algae in a flooded soil is, therefore, believed to be an important contributing factor in nitrogen-recuperation in rice fields.

FIXATION OF NITROGEN BY AZOTOBACTER

The role of bacterial fixation of nitrogen in rice soils was first investigated by Sahasrabuddhe (1936) in Bombay, who observed that rice soils had the power of fixing nitrogen, and that the same was helped by the presence of the crop. From this he concluded that the growing roots of the rice plant helped nitrogen-fixation. Later, Uppal *et al.* (1939), working on the rice soils at Karjat (Bombay), found that *Azotobacter* played an important part in the nitrogen regime in rice soils. They observed that the presence of the growing roots of the rice plant seemed to stimulate and increase the efficiency of bacterial fixation of nitrogen in the soil, and that during the monsoon period, there was an abundance of *Azotobacter* with a simultaneous increase in the nitrogen-content of the soil. Evidence of the fixation of nitrogen by *Azotobacter* in rice soils has, however, been disputed by Sulaiman (1944) and by De and Dutta-Biswas (1952).

The question whether blue green algae or *Azotobacter*, alone or in association with each other, are responsible for the nitrogen fixed in soils is rather difficult to answer, because both the algae and *Azotobacter* exist in association with each other under soil conditions. *Azotobacter* live in the gelatinous sheath usually covering the blue green algae, and it is considered rather difficult to separate the two by ordinary microbial technique.

LOSSES OF NITROGEN FROM WATER-LOGGED SOILS

Losses of nitrogen from water-logged soil have been investigated by a number of workers in the country. Harrison and Aiyer (1913, 1914), while examining the gases produced during the decomposition of green manures in the soil, found small quantities of nitrogen along with methane, carbon dioxide and hydrogen. Sreenivasan and Subrahmanyan (1935), working on the carbon-nitrogen transformation in water-logged soils, observed losses of nitrogen, particularly from the urea and dried blood applied to the soil, and they attributed this to the volatilization of ammonia, favoured by high temperature under the tropical conditions. De and Sarkar (1936), working with Faridpur and Dacca soils, also reported rapid losses of nitrogen occurring under water-logged conditions. De and Digar (1954) have observed losses of nitrogen evolved as gas from water-logged soils, when nitrogenous manures and fertilizers like oilcake, water hyacinth, ammonium sulphate and sodium nitrate were applied. They report that these losses took place after 7 to 12 days of application, and were greater with inorganic fertilizers than with organic manures. Amongst the nitrogenous fertilizers, losses were more with sodium nitrate

than with ammonium sulphate. Besides nitrogen lost as gas, losses of nitrogen in drainage waters were also reported by these authors and are given in Table 66.

TABLE 66. LOSSES OF NITROGEN AS GAS AND IN DRAINAGE WATERS

Treatment	As percentage of nitrogen added			
	Tollygunge soil		Chinsurah soil	
	As gas	In drainage	As gas	In drainage
Oilcake	30.6	48.1	26.6	47.5
Water hyacinth	27.0	41.3	24.4	37.6
Ammonium sulphate.. ..	34.5	30.3	31.4	27.6
Sodium nitrate	44.4	35.5	44.7	33.5

Gupta (1955) has reported nitrogen losses in the form of ammonia gas from applied ammonium sulphate in alkaline soils of *p*H 8.4. He observed that about 22 per cent. of applied nitrogen was lost as ammonia gas from alkaline soils during a period of 15 days of water logging. The rate of loss was about 11 per cent. during first three days, 8 per cent. during next six days and 3 per cent. during the remaining period.

A new scientific approach to the study of water-logged soils started with observations of Pearsall and Mortimer (1939) on the oxidation and reduction zones in the water-logged soil. Japanese workers have also made a comprehensive study of nitrogen-transformation in the water-logged soil. Pearsall (1950) discussed the agricultural implications of oxidation and reduction characters of water-logged soils. Following this work, investigations on nitrogen-changes in water-logged soils were started at the Central Rice Research Institute in 1950. Abichandani (1953, 1956) and Abichandani and Patnaik (1955a) reported nitrogen losses from applied fertilizer under water-logged conditions. Methods and practices to minimise these losses and to get more out of the added fertilizers have been suggested by them to suit different soil moisture and cultivation conditions.

Nitrogen changes taking place in the low land water-logged soil are as follows. The low land rice soil remains water-logged during the entire growth period of the crop, and this, coupled with high temperatures prevailing during the season, brings out a marked depletion of oxygen in the soil profile. Such a condition results in a reduced state of the subsurface layer of the soil. The surface layer of the soil, however, receives oxygen periodically from fresh supplies of irrigation water, and retains its oxidised character. Ammoniacal nitrogen, added in the form of fertilizer, or produced as nitrogen end product of bacterial decomposition in such a soil system, gets oxidised to nitrate-nitrogen in the surface layer of the soil. This nitrate-nitrogen in turn, when leached down to the subsurface reduced layer, is denitrified and decomposes to oxides of nitrogen or free nitrogen, and loses its fertility value. Abichandani and Patnaik (1955a) have evaluated the losses due to

oxidation and denitrification in the low land soils at Cuttack to be about 20 to 40 per cent. of the added nitrogen as sulphate of ammonia, when the fertilizers are applied on the surface soil, as is generally the practice with local cultivators. Besides this, nitrogen-losses from surface-applied nitrogen in the rain-fed tracts have also been observed in the surface-drained waters due to heavy downpour of rain immediately after fertilizer-application. These losses are estimated to be about 10 to 15 per cent. of the applied nitrogen, and vary with the depth of surface water at the time of application, being less with the lower depths of the surface water. To minimise these losses, subsurface placement of ammoniacal fertilizers is recommended, and, the use of nitrate fertilizers is not advocated for low land rice conditions. The subsurface application of the fertilizer makes the ammoniacal nitrogen remain stable in the root-zone of the crop, where it is progressively taken up by the plant. The advantages of subsurface application and the comparison of the availability of nitogen from the surface and subsurface-applied nitrogen have been worked out at the Central Rice Research Institute (unpublished records), and are summrised in Tables 67, 68 and 69.

TABLE 67. NH_4-N AND NO_3-N STATUS OF WATER-LOGGED SOIL WITH SURFACE AND SUBSURFACE APPLIED NITROGENOUS FERTILIZERS*

Fertilizer treatment	Method of application	*Nitrogen (mg. N/100 g. dry soil) increase over control — Number of days after fertilizer application: 7		21		42	
		NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N
Ammonium sulphate at 25 p p m. N.	Surface	1.36	0.10	1.20	—	1.01	—
	Subsurface	2.16	—	2.21	—	2.20	—
Ammonium Nitrate at 25 p p m. N.	Surface	0.81	0.21	0.80	—	0.61	—
	Subsurface	1.12	—	1.10	—	1.10	—

*Results of controlled laboratory studies at 35°C

TABLE 68. NH_4-N STATUS OF WATER-LOGGED SOIL*, WITH SURFACE AND SUBSURFACE APPLIED SULPHATE OF AMMONIA

Method of fertilizer application	NH_4-N (mg. N/100 g. dry soil) — 30 days after fertilizer application	50 days after fertilizer application
Surface	1.70	0.80
Subsurface	2.20	1.30

*Field conditions with standing rice crop

TABLE 69. NH_4-N STATUS AT DIFFERENT DEPTHS OF WATER-LOGGED SOIL WITH SURFACE AND SUBSURFACE APPLIED SULPHATE OF AMMONIA

Profile depth of soil	NH_4-N (mg. N/100 g. dry soil) 14 days after fertilizer application	
	Surface applied fertilizer	Subsurface placed fertilizer
0.0—2.5 cm.	3.5	3.7
2.5—5.0 cm.	2.2	2.8
5.0—15.0 cm.	2.0	3.1

De and Digar (1955) have also studied nitrogen losses from the surface and subsurface-applied sulphate of ammonia from pot experiments and field studies. They observed that the placement of sulphate of ammonia in the sub-soil zone reduced losses of nitrogen. In field experiments on the Chinsurah soil, the nitrogen lost as gas was found to be 22·5 per cent. and 15·6 per cent., with surface application and subsurface placement, respectively.

Advantage of subsurface placement of sulphate of ammonia over surface application in water-logged soil has been shown in a number of field experiments conducted at the Central Rice Research Institute and elsewhere in the country. The subsurface placement has resulted in a higher uptake of nitrogen by the crop, and in increased yield of grain and straw.

DECOMPOSITION OF GREEN MANURES AND ORGANIC MANURES IN WATER-LOGGED SOILS

Harrison and Aiyer (1913, 1914) observed that the decomposition of green manures in rice fields gave rise to relatively large amounts of methane and some carbon dioxide and hydrogen, and, perhaps, some nitrogen in the soil, while the gases in the supernatent waters were mostly oxygen and nitrogen. They noticed a thin film of organism on the surface layer of the soil, which contained both, bacteria and algae, and was responsible for the differential character of gases in the soil and surface water. According to them, bacteria in this film oxidised methane to carbon dioxide, and the latter was utilized photosynthetically by the algae, resulting in the release of oxygen. Thus under swampy conditions, the decomposition of the green manures made the supernatant water rich in oxygen, and this oxygenated water when leached down helped the aeration of the roots of the rice plant. Harrison (1920) has further explained the oxygen regime in the wet soils on the basis that there were bacteria present in the soil that could reduce carbon dioxide by the utilization of hydrogen, and thus the oxygen needs of roots of rice plants were very much reduced by the removal of hydrogen and the lowering of carbon dioxide concentration around the roots of the crop.

The manurial effect of green manuring crops and the release of ammoniacal nitrogen in the soil as a result of decomposition under wet soil state have also been investigated in various States in the country. The results of beneficial effects of green manuring on the growth and yield of rice have been demonstrated by a

number of field experiments all over the country, and the practice of green manuring the rice crop is being widely popularised. In a recent study on the decomposition of green manuring crops under wet conditions conducted at the Central Rice Research Institute (unpublished records), it has been seen that green manuring crops are quick-acting as these rapidly decompose under water-logged state, and nearly 50 per cent. of the added nitrogen is converted into ammoniacal nitrogen in 4 to 6 days, and the rest within 15 to 30 days of application under temperature conditions prevailing in the main rice-growing season.

The decomposition of substances of varying carbon/nitrogen ratios in water-logged soils has been studied by Sreenivasan and Subrahmanyan (1935). They found that the mineralisation was quicker in the case of material of a narrow C/N ratio than with material of wide C/N ratio. They further observed that there was practically no formation of complex nitrogen bodies with substances of narrow C/N ratio, and that the major portion of the added nitrogen is either mineralised or otherwise lost from the soil system, while with a material of a wide C/N ratio, the mineralised nitrogen was mostly present in complex form. It was, therefore, concluded that material with a wide C/N ratio had little immediate fertilizing value, but had delayed and residual manurial values, while the material with a narrow C/N ratio had an immediate fertilizing value.

The quick-acting action of green manuring crops when ploughed into the rice-fields may be attributed to the narrow C/N ratio of the material. Green manures have always been found to be quick-acting fertilizers and give higher yield response than other bulky organic manures like compost and cattle manure. Both compost and cattle manure have a wide C/N ratio, and therefore, the mineralised nitrogen from these gets immobilized in the soil, and is not easily available for crop utilization. These bulky organic manures are, however, found to have delayed and residual manurial values.

MINERALIZING ACTION OF LIME ON SOIL NITROGEN

The organic matter in the rice soils undergoes gradual decomposition on flooding by soil micro-organisms and gets mineralized to ammoniacal nitrogen. All organic nitrogen, however, is not broken up in this manner. Most of it appears resistant, and only a fraction of the total in the soil is mineralized to ammoniacal nitrogen, even after 10 to 13 weeks of water-logging. The increase in soil reaction by the addition of lime has been known to enhance biological activity, and thus release more nitrogen in the soil to be made available for use by the crop. Japanese workers have reported beneficial effects of the use of lime in wet soils, and following this work, the problem of mineralizing action of lime on nitrogen in the rice soils in India has received attention by workers at the Central Rice Research Institute. Abichandani and Patnaik (1955 b) have reported a cent. per cent. increase in the ammoniacal nitrogen-content of water-logged soils due to addition of 2,000 lb. of lime per acre. Results of field experiments showing the beneficial action of lime on the yield of rice are summarised in Table 70.

Yield responses ranging from 10 to 30 per cent. were obtained. Trials conducted over a period of two years confirmed these findings, and, on an average, the additional nitrogen released due to the high dose (2,000 lb./acre) of lime applied

TABLE 70. BENEFICIAL EFFECT OF LIME ON THE YIELD OF RICE AND AVAILABILITY OF NITROGEN IN WATER-LOGGED SOILS

Plot No.	No lime			Lime at 2.000 lb./acre		
	pH*	NH_4-N* ppm	Yield lb./acre	pH*	NH_4-N* ppm	Yield lb./acre
I	6.2	16	2,342	8.1	32	2,817
II	6.5	14	2,576	7.0	34	2,850
III	6.5	14	2,381	7.4	30	2,772
IV	6.4	16	2,381	8.4	34	3,104

*pH and NH_4-N were determined after 14 days of lime application

was equivalent to 20 to 30 lb. nitrogen added as fertilizer. It is recommended that lime be applied to the rice soil at the time of puddling and just prior to the planting of the crop.

PHOSPHATE CHANGES IN WATER-LOGGED SOIL

The behaviour of the phosphate in the water-logged soil is different from that in the upland soil. The phosphate, combining with the iron in the soil, is more available in a water-logged condition, because of the reduction of the iron from the ferric to the ferrous state. This point was stressed by Japanese workers as early as 1942. Investigations on the phosphate changes in water-logged soils have been started at the Central Rice Research Institute, and some of the results achieved during the last few years are summarised below.

(i) Water-logging brought about a marked increase in the available phosphate in the soil. Phosphate extractable by Morgan's Reagent, increased from 1.6 mgm. to 4.1 mgm. of P_2O_5 per 100 gm. of soil after a period of seven days of water-logging.

(ii) The degree of water-logging and depth of standing water over the surface soil had influence on the available phosphate-content. A greater depth of standing water brought about a higher availability of phosphate. The soil with different depths of standing water on the surface showed the following amounts of P_2O_5 in soil solution after a period of 21 days of water-logging.

Depth of water	P_2O_5 in soil solution ppm
Surface film of water	0.09
2.5 cm. depth	0.23
10 cm. depth	0.45

The soil under water-logged condition may, therefore, be considered more fertile from the point of view of the availability of phosphate.

CHAPTER 16

DISEASES

Butler (1913) laid the foundation of the research on rice diseases in India by describing a few diseases, including Blast, and their causal agents. Shaw (1913) followed with his identification and description of Stem Rot. The next major disease of rice to attract attention was Helminthosporiose, which broke out as an epiphytotic in 1918-19 in the delta areas of the Godavari and Krishna. This was investigated by Sundararaman (1922).

Following the identification and description of the diseases, research work was started, principally on Blast and Foot Rot in Madras, on Helminthosporiose in Bombay, and on Stem Rot in the Punjab and the Indian Agricultural Research Institute, then located at Pusa (Bihar). Subsequently, the principal rice-growing States and the Central Rice Research Institute have taken up investigations with a view to controlling the loss in rice production caused by the various diseases. The investigations in progress and results so far obtained are briefly reviewed below.

BLAST

Blast disease of rice was recorded in India by Butler (1913), and since then has been found to be a widespread and destructive disease in the country.

Blast is caused by the fungus, *Piricularia oryzae* Cav. The genus *Piricularia* was classified under Moniliaceae on account of its hyaline spores. But recently Thirumalachar *et al.* (1956) have suggested that the genus should be included in the Dematiaceae along with *Helminthosporium* on account of the grayish sub-hyaline to pale olivaceous conidiophores of all the described species of *Piricularia*, including *P. oryzae*, *P. grisea*, *P. higginsii*, etc.

Loss Caused by the Disease. Only large-scale plant disease surveys can give an objective estimate of the loss in yield caused by the disease, provided an accurate method of correlating a given intensity of the disease with the loss in yield, is available.

The relationship of the severity of neck infection of blast with loss in yield due to the disease is being investigated at the Central Rice Research Institute. Heavy disease incidence is induced by transplanting susceptible varieties late in the season under heavily manured conditions. Variation in the incidence of the disease is brought about by checking the infection in some plots by spraying copper fungicides. The percentage of neck-infection, in each plot, is estimated by suitable sampling at the time of harvest.

In four experiments carried out between 1951 and 1954, it was found that the percentage of neck infection varied between 2.5 and 71.5. Correlation was established between yields of plots and estimated percentage of neck infection. The regression technique was utilized in assessing the loss due to a given degree of neck infection. The data showed that the relation between loss in yield

FIG. 39. Seedlings for artificial infection against blast

FIG. 40. Infecting plants artificially

Fig. 41. Blast-infected leaves

and the neck infection phase of the blast outbreak could be expressed by the equation.

$$Y=1967.95-18.72\ X$$

where Y=expected yield in lb. per acre.

and X=estimate of percentage neck infection.

Based on this, it was estimated that for every one per cent. increase in neck infection, there was a loss in yield of 18.72 lb. per acre or 0.95 per cent. within the range of neck infection and yield obtained in the experiments, Padmanabhan and Ganguly, 1955 ; Padmanabhan *et al.*, 1958 (in press).

Rangaswamy and Subramanian (1957) reported that 60 per cent. neck infection and 40 per cent. nodal infection in *Co. 13*, a short-duration susceptible variety, resulted in 75 per cent. and 41 per cent. loss in grain and straw yield, respectively. The loss in yield computed from the weight of 250 healthy and diseased tillers was 72 per cent., 64.5 per cent. and 4·1 per cent. respectively, in the varieties *Adt. 10*, susceptible, *GEB. 24*, moderately susceptible and *Co. 25*, resistant to blast.

Source of Infection. The disease is claimed to be seed-borne elsewhere, but in India, though the spores of the pathogen have been seen to occur on the blackened kernels of infected ears, no direct evidence is available to show that the disease is seed-borne. On the contrary, it has been found by Krishnaswamy *et al.* (in press) in Madras that sowing infected seeds did not result in seedling infection. Cross-inoculation studies carried out in Madras have shown that the isolates of the fungus occurring on *Panicum repens* and *Digitaria marginata* can infect rice (Ramakrishnan, 1948 ; Thomas and Krishnaswamy, 1948). Recently, Pawar and Kulkarni (1954) observed that *Setaria intermedia* had leafspots resembling those of the Blast of rice and the causal organism was morphologically similar to *P. oryzae*. *Dinebra retroflea* and *Panicum repens* have been recorded as collateral hosts of the pathogen (Thirumala Rao, 1956, unpublished record). How far these hosts help in the perennation of the fungus or serve as potential reservoirs of inoculum remains to be studied.

Spread of Infection. The conidia of the fungus are very light and may be wafted by light breeze to some distance (Reddy and Vaheeduddin, 1956).

Factors Favouring Development of Infection

Temperature: Ramakrishnan (1948) reported that the optimum temperature for the growth of the fungus was 30°C. However, it would appear that lower temperatures are probably more favourable for the infection of the host.

Relative Humidity: It has been observed that a high relative humidity favours the disease outbreak. From the work done in Japan and the U.S.A., it is known that an actual contact with water for 8 to 10 hours is necessary for the germination of the spores on the leaves and penetration into the leaf tissues.

Manuring: The application of excessive nitrogenous manures predisposes the rice plant to infection by Blast (Sundararaman, 1927 ; Thomas, 1938). The increase in the severity of infection resulting from nitrogenous manuring occurs to the same degree both under organic or inorganic forms of nitrogen, applied on equal-nitrogen basis, as far as the neck infection phase is concerned (Krishnaswamy, 1952). As regards, foliar infection, Ganguly *et al.* (1954) found that there was a linear increase in infection with increase in the level of nitrogen applied as ammonium

sulphate, up to 80 lb. nitrogen per acre level, but the organics, compost, groundnut cake and green manure, up to 20 lb. nitrogen per acre level did not have any effect. The effect of increasing levels of nitrogen on blast incidence varied with varieties of different degrees of susceptibility. With increasing levels of nitrogen, the increase in infection is negligible in highly resistant varieties like *Co. 4* (Padmanabhan, 1953a). Both phosphorus and potash, either alone or in combination with nitrogen, have no influence on blast-infection (Krishnaswamy, *l.c.*; Ganguly *et, al. l.c.*).

Age of Host: The susceptibility of the rice plant to leaf-infection due to blast changes with its age; it is most susceptible in the tillering phase following transplanting, and becomes less and less susceptible as it approaches heading (Padmanabhan and Ganguly, 1954).

Physiology of Nutrition of the Pathogen. According to Ramakrishnan (1948), both the rate of linear growth and the weight of the mycelial mat were the highest at *p*H. 7.03. Peptone appeared to be the best source of nitrogen for the fungus. The weight of the mycelial mat increased with increase in C/N ratio, and the best growth was obtained at C/N=5/1. Appa Rao, Saraswathi Devi and Suryanarayanan (1955) stated that thiamine, iron and zinc, and possibly copper, were indispensable for the growth of *Piricularia oryzae.*

Appa Rao, Subba Rao and Suryanarayanan (1955) have also shown that the dialised and autoclaved cultural filtrate of *Fusarium vasinfectum* Atk, has a thiamine replacement value in the growth of *Piricularia oryzae* in culture.

Control. Research on the control of blast has been directed towards the breeding of resistant varieties and the development of economic spray schedules suitable for direct control. Data on the time of appearance of the blast disease, the period of peak incidence, etc., that are being accumulated for each region can be utilised for avoiding the loss caused by blast by suitable adjustments of planting dates within practical limits (Padmanabhan and Ganguly, 1953).

Breeding for Resistance

Selection or Isolation of Resistant Varieties: In the Central Rice Research Institute, a technique has been evolved to test the reaction of rice varieties to the disease. The varieties are first tested for two to three years under artificial infection in seedling stage. Those which are found resistant in these tests are carried forward for field test under natural infection, in which their reaction to the disease in the seedling, post-transplanting and ear-emergence stages is studied for three seasons. Both for artificial infection and field tests, the seedlings are raised under 40 lb. N level and the transplanted crop is raised at 60 lb. N level. Varieties which are selected as resistant at this level are likely to prove resistant under field conditions in India where 40 lb. N level has been determined to be the optimum economic level for rice.

The leaf infection is scored in the manner described below. The scoring is based both on the number of spots as well as the extent of development of individual spots.

NUMBER OF SPOTS

Score 1 — 1=3 spots
Score 2 — 4=15 spots
Score 3 — above 15 spots

TYPE OF SPOTS:

Score A — Just flecks

" B — Reddish brown circular discoloration without zonal differentiation

" C — Circular spots two to three mm. in diameter with a central ashy zone and a dark purplish margin

" D — Broadly spindle-shaped spots, only slightly longer than broader with a central ashy zone, four to five mm. in diameter

" E — Elongated spindle-shaped spots with a central ashy zone, three to five mm. broad and up to 20 to 30 mm. long.

The most heavily infected leaf in a plant is scored and the scores obtained (1D, 2E, etc.) are converted to a numerical scale for the purpose of comparison as follows:

NUMBER OF SPOTS		TYPE OF SPOTS	
Score	Numerical value	Score	Numerical value
1	2	A	1
2	5	B	2
3	10	C	4
		D	8
		E	16

The product obtained by multiplying the respective numerical values for the number of spots and the type of spots is taken as the numerical score for the plant. The average numerical score obtained by all successfully infected plants in a variety is taken as the numerical score of a variety.

For scoring neck-infection in the field, the percentage of plants affected are noted. The following criteria are adopted for evaluation of resistance of a variety.

Very resistant — Numerical score of the variety less than ten in the seedling stage, without D, E spots in tillering stage and with less than 1 per cent. plant with neck infection.

Resistant — Same as above excepting with 1—5 per cent. neck-infection

Moderately Resistant — Numerical score less than ten in the seedling stage, type of spots A, B, C, very rarely D in seedling and post-planting stage, neck-infection 6—10 per cent.

Moderately Susceptible — Numerical score 21 to 30 or slightly more, C, D spots seen in seedling and post-planting stages, neck-infection 11 to 20 per cent.

Susceptible — Numerical score generally 40 and above, D, E spots common in all stages, neck-infection above 20 per cent.

Fourteen varieties, *Bhogjira 1, Sm. 6, Sm. 8, Sm. 9, CP. 6, CP 9, Akp. 8, Akp. 9, S. 67, Mtu. 5, S. 624, H. 755, Ch. 55* and *Ptb. 10* were found resistant and moderately resistant out of the first lot of more than 500 varieties from the genetic stock tested at the Central Rice Research Institute. The reaction of these varieties to blast was tested under field conditions in some 40 centres in various parts of India. The varieties were found to be resistant and moderately resistant in all centres except in Agartala, Kalimpong, Kanke (Ranchi) and Mahabaleswar (Bombay), which are situated at high elevations (up to about 4,000 feet). In these centres the reaction of these varieties except that of *S. 67*, which was resistant, was found to vary widely from year to year. A second lot of 490 varieties from the genetic stock collection, all of early duration, maturing within 120 days, are now being tested for their reaction to the disease.

In Madras State, the following 18 cultures have been isolated as resistant: 3374, 3342, 2744, 3397, 3381, 8348, 8343, 1843, 3273, 2366, 2465, 2364, 1952, 3185, 1914, *Co. 4*, 1201 and *T.K.M. 1*. Of these, *Co. 4*, a selection from the local variety, *Gobi Anaikomban*, maturing in about 200 days, is the most resistant variety to blast found so far in India. *T.K.M. 1* is a single plant selection from the bulk of a short-duration variety.

In Bombay, all improved varieties of the State have been tested for their reaction to blast in the seedling stage under artificial infection, and the varieties, *Antersal-67, Antersal-90, Antersal-200, Mugad-161, Mugad-141, Mugad-249, Mugad-81, Patnai-6, Bhadas-79, Bhadas-6, Krishnasal-10, Waner-1, I-B-12-11, Sathi Dwarf 44-51* and *Sukhvel243-4* have been reported to be resistant.

In Andhra Pradesh, the variety *M. 42*, is reported to be very tolerant to the disease under late planted conditions. *Bcp. 1* and *Bcp. 2*, two selections from *Molokolukulu* considered to be resistant to blast since 1949, have of late been reported to be behaving as susceptible (Narasinga Rao *et al.*, 1956). The varieties *H.R. 1* and *T. 608* have also been reported to be relatively resistant to the disease (Vaheeduddin, 1956, unpublished record).

Hybridization to Evolve Resistant Varieties : At the Central Rice Research Institute crosses have been effected between *Co. 25*, a resistant hybrid strain released from Madras, maturing in 170 days, and *Co. 13*, a high-yielding variety of short duration (120 days), highly susceptible to blast. F_7 and F_8 generations of the crosses are under study for the selection of high-yielding, early-maturing and resistant strains.

In Madras State, crosses were made at Coimbatore, Aduthurai and Buchireddipalem (now in Andhra Pradesh) between *Co. 4*, the resistant parent and some varieties with desirable agronomic qualities, but susceptible to blast. Fourteen cultures were finally selected as resistant from these crosses. Out of the 14 hybrids, *Co. 25, Co. 26* and *Adt. 25* have been released as blast-resistant strains. *Culture No. 6538* will be released shortly, and other cultures are in the final stage of the test. Recently, *GEB 24* and *Co. 4* have been crossed, and a number of hybrids from the cross are showing great promise.

The selections, *T. 6517* and *T. 6522* from the cross *Co. 4* × *Co. 13* are reported to be showing great promise throughout the Madras State in district trials (unpublished records). These cultures were also found to be highly resistant under

severe blast outbreak in Chitoor, Pulla and Buchireddipalem in Andhra Pradesh (Narasinga Rao, 1955).

In Bombay State, several hybridization projects have been undertaken for crossing the local high-yielding but susceptible types with the resistant varieties *Co. 4*, *Co. 25* and *Co. 26* from Madras. Selection for resistance amongst the progenies is in progress.

Research programmes are under way in Andhra Pradesh and Kashmir to breed varieties resistant to blast.

Physiologic Specialisation: Padmanabhan (1953b) tested five isolates of the fungus, two from Cuttack and one each from the Indian Agricultural Research Institute (New Delhi), Coimbatore and Wynad (now Kerala) on nine rice varieties, but no evidence of specialisation in pathogenicity of the isolates was obtained.

Nature of Disease Resistance: Adyanthayya and Rangaswamy (1952) noted that the number of silicated, epidermal, long and bulbiform cells occurred more in the resistant varieties than in susceptible ones. An increase in the dose of ammonium sulphate tended to reduce the number of silicated cells in all varieties. They have also reported (1953) that the number of stomata per unit area in seedling leaves of resistant varieties was relatively less than in the susceptible ones.

Venkatachalam (1954) recorded that though the total uptake of silica might be the same in both resistant and susceptible varieties, the amount of silica absorbed by resistant varieties in two vulnerable stages of growth, i.e., tillering and stem elongation stages, was much greater than in susceptible varieties.

Subba Rao and Suryanarayana (1957) have reported that differences were found in the composition of exosmosed solutes obtained from the leaf surfaces of resistant (*Co. 4*) and susceptible (*ADT. 10*) varieties. While the four amino acids, *viz.*, alanine, methionine, tryptophane and lysine were common to both the resistant and susceptible varieties, the susceptible *ADT. 10* had glycine in addition, and succinic acid characteristically present in the resistant Co. 4, was not detected in *ADT. 10*. Further, two unidentified organic acids were also present in both, although the resistant variety had a higher concentration of these acids. They suggest that under humid conditions, the diffusion of the solutes to the exterior of the host may help in the pre-penetration.

Spraying. Vaheeduddin (1953) reported that a single spraying of Perenox (0·35 per cent.) gave 45 per cent. better yield over the unsprayed plot. He has further reported (unpublished record) that Bordeaux Mixture 5-5-50 (1 per cent.) and Wetcol-15 at the rate of 1 lb. in 25 gallons of water, applied twice after transplanting at 30 days' interval, reduced the infection of blast and gave higher yields. He also found that a single spraying of Bordeaux Mixture 5-5-50 on a eight-week old crop gave 467 lb. per acre more than the control yield of 598 lb. per acre. Experiments at the Central Rice Research Institute showed that 4 sprayings in a season, 2 before and 2 after the flowering of the crop, with any of the fungicides, Bordeaux Mixture (1 per cent.), 'Perenox' (0·5 per cent.), Coppesan (0·5 per cent.), Cupravit (0·5 per cent.), 'Shell copper fungicide' (0·5 per cent.) and Fungimar (0·5 per cent.), were able to control blast effectively. The incidence of neck-infection was also brought down when only two sprayings were carried out after flowering.

The cost of chemicals, required for spraying an acre of crop four times in a season, comes to Rs. 50. Experiments conducted at the Central Rice Research Institute to reduce the cost of spraying have shown that by the use of low-volume nozzles, an acre of crop may be sprayed with only 20 gallons of the spray fluid in the place of 100 gallons required for normal spraying. With the use of low-volume nozzles, therefore, the cost of spraying could be reduced from Rs. 50 to Rs. 10. In severe disease outbreaks, when a 30 to 60 per cent. loss in yield is caused, the increased return obtained through spraying would generally justify this outlay of Rs. 10 on spraying chemicals (Padmanabhan *et al.*, 1956).

Sometimes, copper fungicides have been noticed to injure the foliage of some sensitive rice varieties. Organo-mercurial dusts are reported to have no such injurious effect on rice, but at the same time, are said to be very effective in controlling blast according to Japanese workers. A few organo-mercurial dusts and sprays have been tested at the Central Rice Research Institute for the control of blast and found effective.

HELMINTHOSPORIUM DISEASE

Helminthosporium disease of rice is caused by *Cochliobolus miyabeanus* (Ito et Kurib.) Drechs. ex Dastur=(*Helminthosporium oryzae* Breda de Haan.).

Sundararaman (1922) reported the Helminthosporium disease of rice for the first time in India, and described the causal organism, but the specific determination of the fungus was done later by Mitra (1931).

Loss Caused by the Disease. According to Sundararaman (*l.c.*), the fungus was a weak parasite under normal conditions, and was not likely to cause serious damage of the crop. Padmanabhan *et al.* (1948) confirmed the observation, but mentioned that when an epiphytotic breaks out, almost a total destruction of the crop may be expected. Two such epiphytotics, one in the Godavari delta in 1918, and another in Bengal in 1942, are known. Losses in yield up to 90 per cent. have been recorded during the epiphytotic in Bengal which was considered to be one of the contributing factors to the Bengal famine of 1943 (Report of the Famine Enquiry Commission headed by Sir John Woodhead, 1945).

Source of Infection. According to Thomas (1941), both seed and soil serve as sources of infection. Studies on the viability of the fungus during the period, November-December to June-July, i.e., between harvest and sowing showed that the viability was retained only in seed under natural conditions (Padmanabhan *et al.* 1953). Chattopadhyaya and Chakraborty (1954) found that the fungus did not survive in the soil, but did so only in the stubble. The conidia of the fungus are, however, air-borne (Ganguly, 1946a) and are present in the air throughout the off-season, and may be responsible for the secondary infection seen early in the seed-beds (Padmanabhan *et al. l.c.*). *Echinochloa colona* is reported to be a collateral host of the fungus (Annual Report, Central Rice Research Institute, 1949-51). Another grass, *Leersia hexandra*, is reported by Chattopadhyaya and Chakraborty (1953) to be a collateral host. Whether these grasses serve as foci of infection for the newly sown crop in July remains to be investigated.

Factors Favouring Development of Infection

Temperature: Mitra (1931) noted that 25° to 30°C was the optimum range of temperature for the growth of *Helminthosporium oryzae* in culture.

Thomas (1941) reported that there was a close relationship between soil temperature and seeding-infection. At 15°C the percentages of infection and of dead seedlings were 60 and 42, respectively, but at 29°C, the percentages came down to 38 and 12, respectively. Padmanabhan *et al.* (1953) noted that the seed-borne pathogen failed to cause primary infection of seedlings at temperatures of 28°C and above.

Age of Host: The susceptibility of the rice plant to the disease increased with its age, and it was most susceptible at the flowering or the maturing stage (Padmanabhan and Ganguly, 1954).

Weather: Unusual weather conditions have been observed in years of severe epiphytotic of the disease. Late and heavy rain in November and December was followed by the epiphytotic in the Godavari delta in 1918-19 (Sundararaman, 1922). Unprecedented heavy rains in September and floods, followed by continuous cloudy and humid weather in October-November were found to be associated with the epiphytotic in Bengal in 1942 (Padmanabhan, unpublished record).

Weekly spore catches in aeroscopes for five years at the Central Rice Research Institute show that sudden rise in relative humidity, low range of daily temperature, low solar radiation, accompanied by cloudiness and followed by a period of dry weather in any week, especially during October to January are associated with increase in the conidial population of *H. oryzae* over rice-fields (Annual Reports, Central Rice Research Institute, 1949-50 to 1954-55).

Agronomic Practices: In West Bengal, Chattopadhyaya (1956, unpublished record) found that the application of nitrogen in higher doses increased infection, but P_2O_5 had no effect. He also found that the intensity of infection both on the leaves and the grains was higher when the varieties were grown under transplanted conditions than under broadcast conditions. In an experiment with four dates of planting i.e., 1st, 15th and 31st of August and the 15th of September, both the leaf and grain-infection were the lowest in the crop transplanted on the 15th of August and the highest in the crop transplanted on the 15th of September.

Water-logging. That the disease was more prevalent in a water-logged soil than a normal soil was observed by Das and Barua (1945).

Control. Control of the disease is being attempted by breeding resistant varieties, treatment of seeds with fungicides and hot water, spraying, and adjustment of agronomic practices.

Breeding Resistant Varieties. *Selection or Isolation of Resistant Varieties*: A technique, similar to that described under blast, is followed at the Central Rice Research Institute, for testing the resistance of rice varieties to helminthosporium disease, except that the manuring in the seedling stage is done at a very low level and the scoring of leaf infection is done as follows.

Score:

1 =1-3, undeveloped spots
2 =4-15, undeveloped spots
3 =above 15, undeveloped spots

4 =1-3, developed spots
5 =4-15, developed spots
6 =above 15, developed spots
7 =Broad coalescent lesions covering one-third of the leaf area
8 =Lesion covering two-third of the leaf area
9 =Lesion covering more than two-third of the leaf area

While the number of spots represents the points of successful penetration of the hosts, the extent of development of spots is considered as a measure of the internal resistance of the host tissue to the pathogen. The presence of developed spots represents a higher degree of susceptibility in the variety. This has been taken into account in the system of scoring adopted.

In artificial infection tests in the seedling stage and in field tests, the varieties which get an average score of not more than '3' and have not more than 10 per cent. of the test plants scoring '4' are selected as resistant. Varieties which developed score '5' and above in any of the test plants are rejected as susceptible.

Of nearly 500 varieties so far tested at the Central Rice Research Institute, six varieties, i.e., *Ch. 13*, *Ch. 45*, *T.141*, *Bam.10*, *T.-4982-2A* and *Co.20* have been found to be resistant under artificial infection and natural infection in the field in the seedling and adult stages. The resistant behaviour of the first four varieties has been confirmed in tests carried out in some 40 research centres in different parts of India.

Work on the testing of 490 early maturing varieties from the genetic stocks is now in progress at the Institute.

Varieties reported as resistant to the disease in Bengal (Chattopadhyaya, 1956, unpublished record) are *Ashkata*, *Jhangee*, *Kele*, *Dharial*, *Charnock*, *Bhutmuri* and *Marichbutti* amongst the released *aus* strains, *Bhasmanik*, *Nagra* 41/14, *Seetasail*, *Indrasail*, *Dudsar*, *Nigersail*, *Raghusail*, *Ginnipagal*, *Churuakati*, *Kalikalma* and *Badkalamkati* amongst the released *aman* strains, cultures *N.C.1240*, *O.C.963*, *N.C. 693*, *O.C.335*, *O.C.951*, *O.C.618*, *O.C.952* and *Kataribhog* in the varietal collection, and *Ghatakmuri*, *Gangajali*, *Panlui* and *Honnekuri* among the cultivators' varieties.

Hybridization to Evolve Resistant Varieties: With a view to combine resistance to blast and helminthosporium diseases, a hybridization project has been started at the Central Rice Research Institute by crossing the varieties, *Bam. 10* (resistant to helminthosporium but susceptible to blast) and *Co. 25* (resistant to blast but susceptible to helminthosporium).

Physiologic Specialisation: No evidence for the existence of specialisation in the pathogenicity of the fungus was obtained in preliminary infection experiments with a few isolates obtained from Uttar Pradesh, Madras and Cuttack (Padmanabhan, 1953b) on nine varieties of rice.

Nature of Disease Resistance: Padmabai Pushpanaden (1957) found that the resistant varieties, *Co. 20* and *T. 141* had a relatively higher ascorbic acid content than the susceptible varieties, *Ptb. 10* and *T. 1145*. She has suggested that the higher content of ascorbic acid might be one of the factors contributing to the resistance to helminthosporium disease.

Chattopadhyaya and Chakrobarti (1957) reported that the comparatively more susceptible varieties *Asra 108-1* and *Badshabhog 72* had thinner epidermal layer

and less number of silicated bulbiform cells than the varieties *Patnai 23*, *Bhasamanik* and *Tilahkatchery*, which were considered to be less susceptible. However, there was no relation between the silica content of the leaves and reaction of the varieties to the disease.

Seed Treatment. *Fungicides:* From a number of experiments conducted at the Central Rice Research Institute, it has been found that treatment of seeds with fungicides, such as, Arasan, Phygon, Cuprocide, Agrosan GN, Agrosan special, Fernasan and Y.F. 2776, in the main season (July-December) had no effect on germination, disease development and yield in rice varieties. The crop raised from seed treated with Agrosan special had less disease and gave more yield than the control but the differences were not significant. Of the 11 fungicides tried in the second crop season (January to April), Agrosan special, Yellow Cuprocide, Landisan, Fungi Copper (Giegy) and Copper Sandoz were associated with better germination than control and of these, Agrosan special appeared to be the best. None of the fungicides was associated with higher yield. Chowdhury (1950), however, obtained 24 per cent. increase in yield over control by seed-treatment with Yellow Cuprocide at 6 *tolas* (2.4 ounces) per maund (82 lb.) of seed. An experiment carried out in Uttar Pradesh (Mathur, unpublished record, 1956) with Agrosan GN, Agrosan special, Fernasan and Y.F. 2776 showed that the recurrence of the disease could not be checked by these treatments.

Out of a large number of fungicides tested in West Bengal (Chattopadhyaya, 1956 unpublished record) for control of primary seed-borne infection, Agrosan GN gave the best result. Seed treatment in the case of both *aus* and *aman* varieties, reduced leaf infection but there was no effect on grain infection and yield. In one experiment, treatment of seed of *dharial*, an *aus* variety, with Yellow Cuprocide resulted in reduced grain infection and increased yield. Agrosan GN gave similar results with a few *aman* varieties at Burdwan Farm.

Seed treatment with Agrosan GN at Four ounces per maund (82 lb.) of seed has been recommended in Hyderabad (Vaheeduddin 1956 unpublished record) as a result of field experiments carried out for a number of years.

Hot Water: Complete control of seed-borne infection was obtained by immersion of seeds before sowing for 10 to 12 minutes in water maintained at 53° to 54°C (Chowdhury, 1948). A reduction of infection from 100 to 20 per cent. was obtained by Thomas (1941) by immersion of diseased seeds in water heated to 55°C for 10 minutes.

Treatment of Rice Seeds with Cultural Extract of Helminthosporium oryzae: A considerable degree of resistance to helminthosporium disease could be conferred on susceptible rice varieties by soaking the seeds at germination in a cold water extract of the pathogen, *H. oryzae*. The reaction of the resistant varieties remained unaltered by such a treatment (Annual Report, Central Rice Research Institute, 1949-51).

Spraying. One spraying in the nursery with Bordeaux Mixture 3-3-50, and subsequent sprayings, depending on disease incidence for four weeks after planting, are recommended for the control of the disease in Hyderabad (Vaheeduddin, 1956 unpublished record). Chattopadhyaya (1951) reported a reduction in the air-borne infection by the application of Perenox and 'Dithane Z-78'. Experi-

ments in cultivators' plots in Bengal showed that sprayings with Perenox (0.4 per cent. resulted in the lowering of both leaf and grain-infection and increased yield of grain.

STEM ROT

Stem Rot of rice (Sclerotial disease) is caused by *Leptosphaeria salvinii* Catt.= (*Helminthosporium sigmoideum* Cav.=*Sclerotium oryzae* Catt.).

This disease was first recorded in India by Shaw (1913). Butler (1918) reported the disease to be widely prevalent in practically all the important rice-growing areas of India.

Symptoms. Shaw (1913) stated that the chief symptom of the disease was excessive tillering. Butler (1918), observed that the infected plants showed a tendency to throw out green shoots from the base, when the rest of the crop was ripening and turning yellow. The plants had a high percentage of half-filled grains. The stem of the infected plants was slightly discoloured at the lower internodes, and a dark greyish weft of hyphae was found inside on splitting the culm. Black, shining bodies (sclerotia) were seen dotted all over the inner surface. The lower leaf-sheaths were also often involved, and within their rotting tissue, rows of sclerotia were formed. According to Luthra and Sattar (1936), the most important symptom of the disease in the Punjab was rotting and collapse of the stem.

Loss Caused by the Disease. Butler (1918) reported that this disease was probably responsible in the aggregate for considerable losses, but was easily overlooked owing to the obscurity of symptoms.

During recent years, epiphytotics of the disease caused serious losses in Madras, Kashmir, Coorg and in the Punjab. According to Luthra and Sattar (1936), Paracer and Luthra (1944) and Bedi (1953), the disease destroyed 50 to 80 per cent. of the crop in the Punjab in some years, while losses of 5 to 15 per cent. were common every year. Bedi (*l.c.*) added that during 1952-53, the incidence of the disease was observed to range from 40 to 60 per cent. in a large number of fields in Amritsar, and cause heavy damage, and even at a conservative estimate, the financial loss on this score was not less than four to five million rupees.

Causal Organism. Shaw (1913) stated that in culture, the hyphae were 4 to 6μ broad, and 150 to 350μ long. A transverse septum was found to occur at the point of branching. Frequently, several sclerotia became united, forming an incrustation on the medium, resembling a stroma. This was particularly common in cultures on maize-meal.

Butler (1918) noted the development of peculiar dark brown appendages at the margin of the growth and formation of chlamydospore-like cells through hyphal segmentation, which were barrel-shaped, with thick black walls and oily contents. Sclerotia began to form in five or six days, arising from a plexus of the interlacing hyphae. The mature sclerotium was roughly circular, smooth, black and from 150-500μ in diameter. It showed little differentiation into cortex and medulla, and though it has been said in Italy to become ultimately hollowed out into a cavity containing circular pycnospores, no such change could be observed in Indian specimens and no further stage was seen.

Mundkur (1935) reported that the fungus identified as *Sclerotium oryzae* Catt. possessed coloured hyphae, small, smooth sclerotia and had the ability to change

the colour of some substrates. The cultures of *Sclerotium oryzae* produced conidia of *Helminthosporium sigmodeum* Cav. but not the ascigerous stage. By analogy, however, the fungus was considered to be *Leptosphaeria salvinii* Catt.

Pathogenicity. Both Shaw (1913) and Butler (1918) proved the pathogenicity of the organism in artificial infection studies, and found it to be a virulent parasite.

Mundkur (1935) obtained heavy infection of rice seedlings grown in test tubes of nutrient solution, but not in pots and field. Sclerotia were, however, noted in the leaf-sheath and culms after the crop was harvested. Luthra and Sattar (1936) obtained infection by sowing rice seed or transplanting healthy seedlings into a soil containing diseased rice stubbles or a pure culture of the fungus.

Pathological Histology. In the young infected plants, the hyphae run longitudinally in the large air cavities of the leaf and adjacent cells, and some grow outside the leaves in the folds of the lamina. Penetration takes place through the thin-walled epidermal cells between the vascular bundles (Shaw, *l.c.*)

The hyphae become constricted at the point where the wall is penetrated, and a swelling of the hyphae is formed on the proximal side. Sclerotia develop on the free mycelium lining the inner surface, and also in the air spaces. In artificial infections the infolded leaf-blades in the bud are penetrated, especially from the inner surface where the epidermis has thin walls.

Factors Favouring Development of Infection. Paracer and Luthra (1944) demonstrated that infection could be reduced by late sowing and late transplanting. The disease-incidence was increased by keeping the water stagnant in the fields throughout the growing period. Nitrogenous manures were found to favour the development of the disease. Bedi (1953) reported that successive cultivation in the same field, acid soil, rank and succulent growth of the plant, and insufficient sunlight were also important predisposing factors.

Control. The burning of the diseased rice stubbles *in situ*, erecting strong high *bunds* round infected fields to check the spread of the disease by wind and irrigation water, draining away the water from the field and allowing the soil to bake before subsequent irrigation, balanced fertilization, rotation of crop and planting resistant varieties are the important control measures suggested by the Indian workers [Hector (1931), Paracer and Luthra (*l.c.*) and Bedi (*l.c.*)].

Resistant Varieties. Of the 19 varieties tested by Paracer and Luthra (*l.c.*) in the Punjab, the most resistant were *Basmati-370*, *Basmati-3*, *Mushkan-7*, *Mushkan-41* and *Bara-62*. Hector (*l.c.*) found the variety *Dudsar* to be highly resistant to stem rot in Bengal. In laboratory tests conducted in Uttar Pradesh to study the resistance of seedlings of 20 varieties against stem rot, varieties *T.100* and *N.12* showed the least infection (unpublished communication, Uttar Pradesh, 1956).

FOOT ROT

Foot Rot of rice is caused by *Gibberella fujikuroi* (Saw.) Wollenw. =(*Fusarium moniliforme* Sheld.).

Thomas (1931, 1933) described this disease from India.

Symptoms. Failure of infected seedlings to recover after transplanting seemed to distinguish this disease from the Japanese *bakanae* disease with which it showed many features in common.

Causal Organism. Thomas (*l.c.*) reported that the micro-conidia (*Cephalosporium*) were oblong, hyaline, unicellular, and measured 5 to 13μ $\times$ 3 to 5μ. The macro-condia (*Fusarium*) were hyaline, but pink in mass, elliptical to fusiform, two to five celled and measured 16 to 48μ $\times$ 2.5 to 4μ.

Sundararaman (1933, 1935) identified the causal fungus as *Fusarium moniliforme* Sheld. var *majus* (Wollenw. & Reink.) on account of the size of macro-conidia and pathogenicity on rice. The fungus on comparison was found to be different from *Fusarium heterosporum* obtained from the U.S.A.

Considerable variation was noticed in the behaviour of the culture of the fungus isolated from rice from Maruteru and Coimbatore in Madras. Sub-cultures made of single spore isolations on Richard's agar produced a wide range of saltants, showing differences in the rate of growth and colour, relation of the mycelial growth to the substratum, spore production and pathogenicity on rice. Infection studies with *Fusarium moniliforme* var *majus*, *F. moniliforme* and *F. heterosporum* (*G. saubinetti*) showed that except *F. heterosporum*, all the others were able to kill rice seedlings on inoculation.

Thomas (1931) reported that inoculations through wounds killed seedlings in all stages, and contract inoculations caused death of seedlings and abnormal elongation of tillers in grown-up plants.

Physiology of the Fungus. The thermal death-point of the conidia was found to be 55° to 56°C for a five minute exposure, and 54° to 55°C for a ten minute exposure.

The optimum conditions for the growth of the fungus were a temperature of 28°C, relative humidity of 74 per cent., and a *p*H of 4.83 in solid media, and 5.23 in liquid media.

Factors Favouring Development of Infection. The disease incidence was less in dry nursery than in wet (Sundararaman, 1935).

Nitrogen applied to the soil, either as farmyard manure or as sulphate of ammonia,.stimulated the development of the disease, and this effect was not modified by the addition of potassic or phosphatic fertilizer. A stimulation of the growth of the fungus could also be obtained by the addition of ammonium sulphate and asparagine in the culture medium. *Fusarium moniliforme* being a fungus which enters the seedling before it begins to draw its nutrition from the soil, the evidence available showed that the increased incidence of the disease under nitrogenous manuring was due to the better growth of the fungus rather than to the increase in the susceptibility of the host (Thomas, 1937).

Control. Thomas (1931) suggested the removal and burning of affected plants as one of the control measures for the disease.

Since the disease was found to be seed-borne to a large extent, a considerable measure of control could be effected by seed treatment. Thomas (1933) and Sundararaman (1933) tested different wet and dry treatments with a number of fungicides. Most of the treatments had a beneficial effect, some of the more effective treatments being, soaking for 15 minutes in 1 per cent. formalin, 'Uspulun' (30 minutes in 0.5 per cent.) 'Granosan' (1 gm. per lb. of seed), hot water (immersion for 30 minutes at 55°C), Copper sulphate (immersion in 2 per cent. solution for 30 minutes), Ceresan brand Tillantin (1 gm. per lb. of seed), Ceresan mercuric chloride,

etc. Of these, Granosan and Ceresan were recommended, as they were dry treatments; wet treatment with fungicides often proved injurious to seeds.

Further experiments conducted in Madras have confirmed that organo-mercurial seed dressings were superior to other types of formulations in controlling foot rot. The most effective dose was 0.6 per cent. by weight of seeds. Even at this level, the germination of seeds was not affected Krishnaswamy *et al.* (in press).

Sundararaman (1933) compared the relative efficacy of seed treatment with copper sulphate (2 per cent. solution for 30 minutes), seed-bed treatment with copper sulphate (1 per cent.), seedling treatment (4 per cent. Bordeaux mixture just before transplanting), and field treatment (1 lb. of copper sulphate for one per cent. of transplanted area) in controlling foot rot. He found that seed treatment and seed-bed treatment were significantly superior to seedling treatment.

Resistant Varieties. Thomas (1933) tested the reaction of 41 varieties of rice to foot rot, and found that while none of the varieties tested was immune, *Wateribune*, an American variety, *Aryan* and *GEB.24* were highly resistant.

Sundararaman (1933) reported that *GEB.24* was absolutely immune, and *Kistnakatukulu, Akkulu, Nallarlu, Atragada, Venkisannam, Adt. 15, Aryan* and *Co.1* showed high resistance to the disease.

Krishnaswamy *et al.* (in press) has reported that the variety *Ptb. 7* was consistently resistant to the disease.

GEB.24 and *Ptb.7* have been reported to be resistant to the disease in Andhra Pradesh.

Nature of Disease Resistance. Andal and Subba Rao (1956) examined 6 and 12 days old healthy and diseased seedlings of *GEB.24*, a resistant variety, and *Mtu.9*, susceptible, for the amino acid distribution. In the healthy plants of both ages, glutamic acid, tyronine, methionine, tryptophane and lysine were present in the roots of both resistant and susceptible varieties ; in addition there was alamine and aspartic acid in the roots of the susceptible variety but not in those of the resistant variety. In the shoots, in addition to the amino acids mentioned above, proline was also present.

There was no difference in the amino acid content between 12-day old infected and healthy plants except for an unidentified new nin-hydrin substance possessing low RF value in the roots and the disappearance of proline in the shoots of plants showing *bakanae* symptoms. In plants showing chlorosis of leaves only, serine, glycine and phenyl alamine appeared in the roots while methionine disappeared ; in the shoots of such plants serine, glycine and phenyl alamine and the unidentified nin-hydrin positive substance appeared instead of glutanic acid proline and methionine present in the healthy shoots of the susceptible variety. The amino acid composition of the resistant plants grown in infected and uninfected soil was similar.

PHYSIOLOGICAL ROOT ROT

This disease was first described in India as *Pansukh* (leaf-drying) by Dastur (1937), and has since been noticed in West Bengal (Gupta, 1954), Bihar (unpublished reports), Orissa (Annual Report, the Central Rice Research Institute, 1953-54) and Uttar Pradesh (unpublished reports).

Dastur (*l.c.*) drew attention to the fact that the root system of affected plants is attenuated, consisting of mostly coarse or water roots, and without the dense mat of fine secondary rootlets found in all healthy plants. In this respect, the disease bears a close resemblance to other well-known diseases like the *Mentek* of Java and the *Straight-head* of the U.S.A.

Neither Dastur nor the subsequent workers found any specific associated organism, but the disease has been noticed to occur under conditions of poor drainage in West Bengal, Bihar, Orissa and Uttar Pradesh. Gupta (1954), working in West Bengal, found that there was an accumulation of reduction products in the root-zone of the affected plants.

In Bihar and the Central Rice Research Institute, it was found that drainage of water followed by the application of a light dose of a fertilizer, 50 to 60 lb. of ammonium sulphate per acre, helped the plants to recover from the leaf-tip drying symptoms.

Under conditions of severe infection, the variety *Bondu* was found resistant in Madhya Pradesh. At the Central Rice Research Institute, the varieties *Ptb.10, Adt.4, Adt. 15* and *Benibhog* were found resistant to the disease. Examination of root system showed that the resistant varieties possessed a dense mat of fine secondary rootlets even under severe water-logged conditions.

NARROW BROWN-LEAF SPOT

The Narrow Brown-leaf spot is caused by *Cercospora oryzae*, Miyake.

The disease was first reported from India by Ganguly (1946b), who described the symptoms of the disease and observed that the conidia of *Cercospora oryzae* had a tendency to form chains.

The disease is reported from Orissa and West Bengal only at present, but it probably occurs in other parts of India also.

STACKBURN DISEASE

Stackburn disease is caused by *Trichoconis padwickii* Ganguly.

This disease was first reported from India by Padwick and Ganguly (1945), who isolated the causal organism from diseased seeds, and presented a description of the same on the basis of morphological and cultural studies. Ganguly (1947) described the symptoms of the disease on seedlings and leaves and grains of adult plants, and described the fungus as a new species, *Trichoconis padwickii*.

The fungus has been found to infect a wild grass in the rice-fields in Dacca (Padwick, 1950) and also to cause a disease of *Crotalaria verrucosa* L. (Salam and Rao, 1954).

The disease is reported from Orissa (Mohanty, unpublished record, 1956), West Bengal (Chattopadhyaya, unpublished record, 1956), Uttar Pradesh (Mathur, unpublished record, 1956) and Madras (unpublished record), but is of minor importance at present.

UDBATTA DISEASE

Udbatta disease is caused by *Ephelis oryzae* Syd. The causal organism of the disease was first described from India by Sydow (1914). Narasimhan and

Thirumalachar (1943) considered the causal organism to be the conidial stage of an ascomycete, which they named as *Balansia oryzae*. In Mysore, Venkatakrishnaiya (1946, 1952) reported *Ephelis oryzae* on the three grasses, *Eragrostis tenuifolia*, *Isachene elegans*, *Echinocloa crus-galli*, and also on *Setaria italica*. Mohanty and Mohanty (1957) have recorded *Ephelis oryzae* on the following grasses in Orissa: *Paspalum scrobiculatum*, *Brachiaria ramosa*, *Digitaria marginata* var. *fimbriata*, *Ischaemum aristamum*, *Saccolepsis myosuroides* and *Echinochola colona*.

The ephelidial stage of this pathogen was found on two more grasses, *Pennisetum hohenackeri* and *Digitaria marginata* in the Araku valley of Andhra Pradesh (Govinda Rao and Reddy, 1956).

Kamat and Patel (1951) reported that 9 to 11 per cent. of the plants were infected in North Kanara district, Bombay State, and the disease was gaining importance in the State. The disease occurs in Bihar, Andhra Pradesh, Hyderabad and Orissa and is also reported to have caused considerable loss in yield of rice in the Koraput area of Orissa during 1953.

No control measures have been worked out so far, as it is a minor disease.

FALSE-SMUT

False-smut is caused by *ustilaginoidea virens* (Cke.) Tak.

The disease was first described from India by Cooke in 1878. Raychaudhuri (1946) reported that the pathogen infects the plants either at the time of opening of flowers or when the grains are mature.

Govindarao and Gopala Raju (1955) observed the incidence of false-smut in Andhra Pradesh during 1953 and 1954, and found that rainfall accompanied by cloudy days during the period of flowering to maturity of the grain seemed to increase the incidence of this disease.

Govindarao and Venkata Reddy (1955) observed the pathogen occurring on the wild rice, *O. officinalis* in Andhra Pradesh.

As a full knowledge of the causal organism is not available, no specific control measures have been suggested.

BUNT

Bunt of rice is caused by *Neovossia horrida* (Tak) Padwick and Azmatullah Khan.

Butler (1913) reported the disease from India and identified the causal fungus as *Tilletia horrida* Tak. Padwick and Azmatullah Khan (1944) considered the Bunt to be *Neovossia*. The disease is recognised by the presence of blackened mass of spores on the surface of the affected grains, which are sometimes half-opened at the top extruding the spores. Very few grains in a panicle are infected. Though Reyes (1933) and Camus (1935) in the Philippines (1933) reported that the infected plants were stunted and had fewer tillers than the healthy ones, Chowdhury (1951) working in Assam could not find any significant difference between healthy and infected plants in these respects.

During the course of six years of study on the disease in Assam, Chowdhury (1951) found that the disease did not occur on *ahu* and *boro* rices; amongst the *aman* and *asra* groups, 0.05 to 1.5 per cent. of plants were generally found bunted; but

in *sali* rices, though normally 0.5 to 17.5 per cent. were only bunted, in exceptionally favourable years for the bunt outbreak, 10 to 52 per cent. of the plants have been found to be infected. The number of grains infected in a panicle was generally low, being never more than 2.5 and very rarely up to nine. Therefore, the disease, on the whole, was not considered of much economic importance. A similar conclusion, that the disease was not of much economic importance, was reached by Salam and Rao (1953) during the course of their studies on the disease in Hyderabad (Andhra Pradesh).

Mundkur (1945) had suggested that the bunt infection may occur through sporidia at flowering. Chowdhury (1946) was able to confirm that infection could occur through sporidia at flowering by successfully inoculating 72 out of 97 ears of rice at anthesis by using Moore's vacuum method. Further studies by Chowdhury (1946) on the mode of infection of bunt showed that neither seed-borne nor soil-borne infection was likely to occur.

No control measures have been advocated as the damage due to this disease is negligible.

GRAIN SPOTS

Spots were found to occur in the seeds of all rice varieties; the early maturing varieties, the flowering and maturity of which coincided with the late monsoon at Cuttack, had a higher percentage of spotted seeds than the varieties of longer durations. The organisms associated with the grain spots were mostly *Trichoconis padwickii, Helminthosporium oryzae, Curvularia lunata, Rhizopus nigricans, Chaetomium indicum, Chaetomium brasiliensis, Chaetomium brasiliense, Helicoceras nymphaearum, Phoma* sp., *Cephalosporium* sp., *Penicillium* sp. and *Aspergillus* sp. Spotted seeds had lower weight and poorer germination than healthy seeds. Seeds treatment with fungicides could not improve the germination of spotted seeds significantly, though some beneficial effect was noticed in a few varieties (Annual Reports, Central Rice Research Institute, 1948-53).

BACTERIAL BLIGHT

A disease of the foliage resembling the *kresek* of Indonesia was reported for the first time in 1951 from the Khopoli area of Bombay (unpublished report). The disease is said to be of bacterial origin (unidentified) and found to cause considerable damage to rice in Kolaba and Maval districts of Bombay. The mode of infection of the disease is not known, but it infects leaves and leaf-sheaths, the bacteria spreading through the xylem vessels.

A similar disease has been observed at the Central Rice Research Institute for the last three years.

A project for breeding resistant varieties has been taken up in Bombay through the hybridization of the Indonesian and Kanpur varieties, reported to be resistant, with local standard strains. The following remedial measures also have been recommended.

1. Clean cultivation
2. Spraying of the nurseries or fields with Bordeaux Mixture (3: 3: 50) or any other copper fungicide.

UFRA

The disease has been studied in detail only by Butler (1913, 1919) who proved that nematodes, identified as *Tylenchus angusta*, were responsible for the peculiar symptoms of the disease. The worms crawl up the seedlings and enter the bud region. The tissues are not bodily penetrated, but the worms insert their stylets into the epidermal cells, and suck out the sap. As the seedlings grow, the worms move up into the young tissues. The parasitization of the differentiating tissues of the earhead primordia results in the poor emergence of earheads, and the development of deeply stained malformed spikelets.

The worms survive in moist soil and stubble, and perhaps also in the grains, and infect the new crop. Stagnation of water helps in the rapid spread of the disease, favouring the migration of worms to the neighbouring plants.

The worm is now named as *Ditylenchus angustus* (Butler) Filipjev.

CHAPTER 17

PESTS OF RICE

Authentic records of rice pests date as far back as 1880 when Cotes reported the incidence of *Pachydiplosis oryzae* in Bihar, (Indian Museum Notes, Vol. I, 1889). The monumental works of Maxwell-Lefroy (1909) and Fletcher (1914), which are known all over the world, contain valuable information on rice pests. Systematic study on crop pests was initiated in India during the early years of this century and pioneers in this field were Ghosh in Burma (then part of India), Ramakrishna Ayyar and Ramachandra Rao in South India and their investigations are reported in the Proceedings of the Entomological Meetings, Pusa (1919-1923). Since then, considerable progress has been made in the study of rice pests and their control measures in the various States. The available information on the subject is presented below.

STEM BORER

Cultural methods based on the principle, 'prevention is better than cure' include the collection and burning of stubbles after harvest and flooding and ploughing the fields to destroy the pupal and pre-pupal population of borers. A systematic collection of egg-masses in the field and moths at light traps is also recommended. These methods, no doubt, reduce the pest population to some extent. Experiments in Hyderabad show that the crop planted with seedlings from which no egg-masses were removed in seed-beds suffered a loss of over 40 per cent. The removal of the dead hearts is a remedial measure adopted in Assam, Mysore and Orissa, but the ravages of the stem borers remain unabated, as very often the larvae do not come along with the dead hearts pulled out. Further, the removal of the dead hearts in a field is laborious and not economical.

Cultural operations to adjust the planting of the crop to escape pest infestation are not easily practicable. The study of the seasonal abundance of the stem borers in various States shows that there is a large fluctuation in the number and occurrence of broods. There are three broods in a year in West Bengal, the first from middle of February to late April, the second from middle of May to late June, and the third from the middle of August to late October. In Bihar, the pest is prevalent from May to September. In Hyderabad, four broods are distinguished, the first from the end of May, the second from the end of July, the third from the end of September, and the fourth from the end of March. Further, it has been found that a crop raised before January 15 is subject to borer attack. At Cuttack, two main broods, *viz.*, one during November-December, and the other during February-April, are distinguished with a considerable overlapping of generations. The first brood attacks the late-planted monsoon crop and the seedlings of the summer crop, causing white earheads in the former and dead hearts in the latter. The second brood attacks the summer crop at the shot blade stage, causing either white earheads or earheads with partially filled or unfilled grains.

With the introduction of chlorinated hydrocarbons and organo-phosphorus compounds, trials for more effective methods of control have been in progress in the various States. In the Punjab and Madras, dusting 5 per cent. BHC or DDT is recommended. Investigations at the Central Rice Research Institute on the different methods of application of these chemicals show that dipping seedlings in 0.20 per cent. BHC prior to transplanting, followed by spraying the crop with 0.20 per cent. BHC, or dusting five per cent. BHC five times till flowering, gave a significant control of stem borers and increased the yield by 32 per cent. Work on the efficiency of BHC has indicated that its toxicity lasts for five to seven days on sprayed plants and for three to five days on dipped seedlings and hence spraying five times is found necessary. Laboratory studies indicated that moths did not lay eggs for five days on plants sprayed with BHC. Further, spraying had no effect on the egg masses (Central Rice Research Institute, Annual Report, 1951-52).

In West Bengal, BHC-0·1 per cent. spray is found to be the best in controlling stem borers when sprayed four times, at intervals of 15 days commencing from a week after transplanting. The efficacy of the insecticides tried in this State has been found to be in the following descending order: BHC-0·1 per cent. spray, BHC-5 per cent. dust, DDT-0·1 per cent spray, DDT-5 per cent. dust, Folidol-5 per cent. dust, Toxaphene 5 per cent. dust, Toxaphene-0·1 per cent. spray, and Folidol-0·04 per cent. spray.

In Hyderabad (Andhra Pradesh), one spraying with Folidol-0.06 per cent. or Endrin 10 c.c. per gallon at flag leaf emergence is found to reduce the white ears by nearly 55 per cent. The efficacy of the insecticides tried was found to be in the following descending order: Folidol-0.06 per cent., Endrin 10 c.c. per gallon, DDT-0.25 per cent., Metasystox-0·10 per cent. and BHC-0·25 per cent. It has also been reported from Andhra Pradesh that spraying the nursery and the transplanted crop at fortnightly intervals with Endrin-0·03 per cent. or Parathion-0·05 per cent. or Folidol-0·03 per cent. has contributed largely to a reduction in the borer incidence.

In Bihar, three sprayings at fortnightly intervals with Folidol-0.04 per cent. were found sufficient to control the pest to a considerable degree.

Spraying 'Folidol'-0.02 per cent. in the early stage, and Folidol-0.05 per cent. at the earhead stage of the crop is recommended for controlling this pest in Mysore.

In Madras, timely application of Folidol-0.05 per cent. or BHC-0.1 per cent. twice or thrice depending upon the prevalence of the pest, reduced the borer incidence. The efficacy of the different insecticides tried in this State is in the following descending order: Folidol-0.05 per cent. spray, BHC-0.1 per cent. spray, BHC-10 per cent. dust, and a combination of BHC-10 per cent. dust and DDT-5 per cent. dust (Ananthanarayana *et al.* 1954).

Investigations at the Central Rice Research Institute indicated that Endrin -0.04 per cent. and Folidol-0.08 per cent. possess high insecticidal potentialities in that they retain toxicity for longer periods. Moths did not lay eggs on plants sprayed with Endrin and Folidol for 8 and 12 days, respectively (Central Rice Research Institute, unpublished records).

The efficacy of different insecticides studied in spraying trials at the Central Rice Research Institute, was found to be in the following descending order: "EPN-

300' 0.4 per cent. Folidol 0.1 per cent., Basudin-0.04 per cent., Systox 0.1 per cent., Endrin 0.04 per cent., and Ekatox 0.1 per cent. It is necessary that precautions should be taken in using the above insecticides as they are toxic to warm-blooded animals as well. Irrigating the rice plant with Folidol 0.1 per cent. periodically till flowering resulted in an almost complete control of stem borer incidence (Israel and Veda Moorthy, 1954). In Mysore, adopting a different technique, irrigation with Folidol did not give the same beneficial result as when sprayed on the plant (Puttarudriah and Appanna, 1955).

The conclusions on the study of the efficacy of insecticides in different States are not same. This is due to the differences in dosage, method and time of application. Hence, a co-ordinated research on all-India basis to evaluate the comparative efficacy of various insecticides is necessary.

Egg-masses of *Schoenobius incertulas* and *Scirpophaga innotata* are covered with buff-coloured hairs, making it difficult for the insecticide to reach the eggs. Since the insecticides are not effective in destroying the eggs due to this dense covering of hairs and since the larvae remain concealed, insecticidal treatments have got to be directed against the ovipositing adults and the newly hatched out larvae. In the studies conducted at the Central Rice Research Institute to find out an effective method of spraying, it was found essential to determine the time of brood emergence or the prevalence of moths by studying the number of moths caught at light traps daily to arrive at the correct timing of any insecticidal application. Dusting BHC-5 per cent. twice in the nursery according to brood emergence, is sufficient to prevent seed-bed infestation. Dipping seedlings prior to transplanting in an insecticidal solution of either Folidol -0.08 per cent. or Endrin -0.04 per cent. checks the egg-laying by moths which may emerge soon after transplanting. Spraying in the field crop should be so timed as to synchronize with the brood emergence. Depending upon the brood emergence, spraying should be done twice during the growth phase of the crop and twice during the shot blade stage. The first spray in each stage kills the adults and checks oviposition, while the second spray, to follow within a period of eight to ten days after the first one, would be effective against the hatched out larvae.

Spraying Folidol -0.08 per cent. according to the above schedule reduced stem borer infestation by 83.79 per cent. and increased the yield by 54.26 per cent. Spraying BHC or DDT at 0.2 per cent. is also effective, but as their residual toxicity is very low, the number of sprayings has to be increased accordingly (Central Rice Research Institute, unpublished records).

Though considerable success has been achieved by these methods, they can be only an adjunct to the biological method, which has not been exploited, and for which there is considerable scope.

In the search for indigenous parasites for biological control at the Central Rice Research Institute, the following new parasites have been brought to light: *Aprostocetus israeli* Rao on grubs of *Chilo* spp., *Syntomosphyrum israeli* Rao on eggs of *Schoenobius incertulas*. The extent of natural parasitisation of *Schoenobius* eggs was found to be 55 per cent. (Israel, 1955).

In an experiment conducted at the Central Rice Research Institute, to study the influence of fertilizers on the incidence of stem-borers, it was found that the per

centage of white earheads was significantly more in the plots with high levels of nitrogen given as ammonium sulphate, than either in the unmanured plots or in the plots with phosphatic fertilizer alone. There was no significant difference in the percentage of white earheads between the plots with phosphatic fertilizer alone and the unmanured plots.

Studies on the varietal susceptibility to stem borers indicated that in general no variety was resistant. But scented varieties recorded a higher incidence than green non-scented varieties at Cuttack. (Central Rice Research Institute Annual Report, 1954-55).

Schoenobius has been noted on the following collateral hosts: *Cynodon dactylon, Cyperus rotundus* and *Paspalum* sp.

The incidence of stem borers in relation to tillering showed that the attack at the vegetative phase of the crop resulted in subsidiary tillering to compensate for the dead hearts. But these newly formed tillers remain green till harvest, and do not contribute to the yield in short duration varieties. Infestation in tillers at the shot blade stage sometimes resulted in branches at higher nodes, but the earheads of these branched tillers usually remained green and unset at the time of harvest (Central Rice Research Institute, unpublished records).

Experiments have been conducted at Hyderabad (Andhra Pradesh) and the Central Rice Research Institute to estimate the loss due to stem borers. At Hyderabad the method adopted was to count the number of white earheads in a 10 per cent. sample and to compute the loss from the weight of grain in an equal number of sound grain-bearing earheads.

Though the stem borers damage the crop at the growing phase and at the shot blade stage, resulting in dead-hearts and white earheads, respectively, the damage done at the shot blade stage alone is generally taken into account while estimating the loss due to stem borers, as the presence of white earheads at this stage is very spectacular. The loss caused at the earhead stage of the crop was estimated at the Central Rice Research Institute, and it was found that for every unit per cent. increase in the earheads the decrease in yield was 0.604 per cent. (Israel and Veda Moorthy, 1955). But, in estimating the loss due to stem borers, the loss caused at both the stages should be considered. In an experiment conducted at the Central Rice Reseach Institute, it was found that the loss at the early seedling stage was 21.57 per cent. and the loss at the earhead stage was 26.99 per cent., while the cumulative loss at both the stages was 44.15 per cent. (Central Rice Research Institute, unpublished records).

GALL FLY

The rice gall fly is prevalent throughout the monsoon in all the States of the Indian Union. In Hyderabad (Andhra Pradesh) the crop sown between the last week of July and the first week of August is subject to severe infestation. It is reported from Madras that for the crop transplanted in June, a cloudy and rainy weather during the second fortnight of July, followed by a bright and hot weather during the first fortnight of August, brings about a high incidence. During the peak period of infestation (end of August to end of November) at the Central Rice Research Institute, the temperature ranged from 23.1° to 30.9°C and humidity

from 79.1 to 88.8 per cent. (Central Rice Research Institute, unpublished records). Investigations on the incidence of the gall fly in relation to season and age of crop showed that infestation was always higher in a 90 days old crop than 60 days old crop, irrespective of the date of planting (Central Rice Research Institute Annual Report, 1953-54). Growing early varieties which come to flowering before the peak period of the pest has been recommended, but such early varieties are generally poor in yield.

Weeding of alternate hosts and setting up light traps to capture gall flies are commonly adopted in all the States. Dusting with BHC-10 per cent. at the oviposition stage in Andhra Pradesh, and spraying Folidol-0.04 per cent. or Endrin -0.02 per cent. in Bihar have been found to check the spread of this pest. The use of Parathion has proved promising in Bombay, Mysore and Madras States.

As the newly-hatched grub does not wander about much outside and as the grub on entering into the stem remains protected, control by insecticides is difficult. Timing the spray operations against the adults is essential as in the control of stem borers. At the Central Rice Research Institute, spraying with Folidol-0.08 per cent. four times during the vegetative phase of the crop to synchronise with the brood emergence reduced incidence by 48.0 per cent., resulting in an increase in yield by 15.0 per cent. (Israel and Veda Moorthy, 1955).

The natural parasitisation of gall fly grubs was found to be 89.0 per cent. between the end of October and November. Two new parasites on the grubs of *Pachydiplosis oryzae* were found at the Central Rice Research Institute: (i) *Proleptacis oryzae*, (ii) *Telenomus israeli* (Israel, 1955). In Hyderabad, the percentage of natural parasitisation of gall fly grubs by *Platygaster oryzae*, C., ranged from 15.3 to 100 between the end of August and the beginning of September.

Studies on varietal reactions to the gall fly indicated that some local varieties, such as *Dahia, Bachha, Kalma, Dhusari* and *Teba* are more susceptible in Bihar. In Bombay State, varieties *White Halga 1690, Maskatay 1315, Red Halga 244*, and *Jaddu 1061* are reported to be more susceptible. Reports from Hyderabad show that variety *H.R. 14* has a low incidence, and varieties with purple sheaths are highly susceptible, when sown late. In Madras, the variety *MGL-5* is found to be comparatively resistant. At the Central Rice Research Institute, however, it has been found that green non-scented varieties have a higher infestation than green scented or purple-pigmented varieties, and the infestation was higher in varieties which have a high tillering capacity (Central Rice Research Institute Annual Report, 1950-51).

Wild grasses in the vicinity of rice-fields *viz.*, *Paspalum scorbiculatum, Hemarthria compressa, Cynodon dactylon*, and *Bothrichloa pertusa*, in Bihar, and *Eleusene* sp. *Panicum* sp. and *Panicum crusgalli*, at Cuttack, have been reported as collateral hosts.

Studies on the effect of gall fly infestation on tillering showed that the attack in the vegetative phase of the crop induces vigorous subsidiary tillering. These tillers may come to flower if not reinfested.

The estimation of loss caused by the gall fly showed that for every unit per cent. increase in incidence of gall fly, there was a loss of 0·5 per cent. in yield (Israel and Veda Moorthy 1955).

RICE BUGS

Mechanical methods like hand-picking, collection of adults and nymphs by baits, attracting bugs at lights or with meat baits are the common measures adopted for control. Dislodging nymphs by drawing large bamboo poles over the plants, smoking, and burning trash are also suggested as remedial measures (Narayanan, 1953a).

Studies on the seasonal abundance of these bugs at Cuttack indicated that the infestation was severe when the temperature was 27° to 28·2°C, and humidity 80·6 to 82·1 per cent. In Madhya Pradesh, the peak of incidence is avoided by planting early-maturing varieties which ripen at the time of pest out-break.

At flowering time, the rice bugs migrate from the grasses. The unequal ripening of the fields enables the swarms of bugs to multiply rapidly, and successive generations migrate from the earlier to the late-flowering varieties, with the result that they become a serious menace to the late-flowering varieties.

In Madhya Pradesh, DDT-5 per cent. dust, and in West Bengal, Chlordane 2·5 per cent. dust, or 0·2 per cent. spray are recommended for the control of this pest. In Bihar, the Punjab, Orissa and Mysore State BHC-5 per cent. dust is used for an effective control. At the Central Rice Research Institute, trials with different insecticides showed that dusting 5 per cent. DDT. or BHC effectively controlled the pest (Israel and Rao, 1954a). It is reported that when Systox was applied as a watering agent, the plants remained free of bugs (Sen and Srivastava, 1955). Systox is a highly poisonous organophosphorus compound, the use of which involves many hazards and cannot be popularised at this stage.

In Bihar varieties *Kolaba* and *Ch. 10* are reported to be highly susceptible, and the variety *Sona* fairly resistant. In Madras, the variety *Mundagakutty* is reported to be less affected by this pest. At the Central Rice Research Institute, the awned varieties are found to be less susceptible than awnless varieties (Israel and Rao 1954b). Painter (1951) states that *Sathia* varieties are resistant to rice bugs because the panicle remains enclosed in the leaf-sheath, and offers mechanical resistance.

Rice bugs have been recorded on the grasses, *Panicum colonum*, *P. crusgalli*, *P. barbatum*, *Digitaria sanguianalis* and *Paspalum dilatatum* in Orissa, and on *Panicum miliare*, *Elusium aegypticae* and *Setaria glauca* in Bihar. The bugs are known to hibernate on *Clerodendron infortunatum* in Bihar.

RICE HISPA AND LEPTISPA

Uprooting of grasses and keeping the *bunds* clean is a commonly adopted control measure. Dragging a kerosenated rope over the infested crop and clipping affected leaf tops are mechanical methods of control advocated.

In West Bengal, rainfall is reported to have a negative effect on the activity of Hispa. Five broods have been recorded in Hyderabad, and infestation is reported to be serious if there is no rainfall in August. In Assam, low-lying areas with high humidity are reported to be preferred by both Hispa and Leptispa.

The incidence of Hispa in relation to cultural and agronomic practices was studied at the Central Rice Research Institute, and it was found that the pest preferred young plants partly submerged in water. During the period of severe infestation, hot and humid conditions prevailed, the temperature ranging from

2·7·8° to 33·4°C and humidity from 75 to 98 per cent. (Central Rice Research Institute Annual Report, 1948-49).

Spraying lead arsenate or DDT, dusting Pyrodust or BHC have been found effective in controlling Hispa in Hyderabad. Insecticidal trials in West Bengal with BHC, DDT, Toxaphene and Folidol indicated that dusting was more effective than spraying. In Bihar, Mysore, Andhra Pradesh and the Punjab, dusting with BHC-5 per cent. is adopted. At the Central Rice Research Institute, a cent. per cent. kill was obtained within 4 hours after spraying DDT-0·2 per cent. Further investigation on insecticidal control have indicated that dusting BHC-5 per cent. or spraying BHC-0·2 per cent. is also effective in controlling adults of both Hispa and Leptispa. Spraying Folidol -0·08 per cent. or Endrin -0·04 per cent. controls both the adults and the mining grubs on the leaves.

Vetiveria zizanioides has been noted as an alternate host in West Bengal.

ARMYWORMS AND CUTWORMS

Age-old methods of control like flooding the seed-beds, spreading a film of kerosene oil, digging trenches around affected fields, collection of larvae and setting up light traps are reported to be still popular in Mysore, Orissa and Assam. Providing perches in affected fields for predatory birds which feed on the larvae is adopted in Madras.

In Mysore, dusting calcium arsenate when the fields are dry or spraying BHC or DDT is being advocated. In Bombay State, the spraying of BHC-0·2 per cent. gave an 85 per cent. control of *Spodoptera*. Dusting BHC 5-10 per cent. is the usual recommended dose for the control of *Cirphis* and *Spodoptera* in Andhra Pradesh, Bombay, Hyderabad, Madras and West Bengal. Insecticidal trials at the Central Rice Research Institute show that BHC-5 per cent. dust or 0·2 per cent. spray or Folidol -0·1 per cent. spray is effective in controlling these pests, (Israel *et al.* 1955).

GRASSHOPPERS

As the eggs are laid in the soil and in the stubbles, scraping field bunds and ploughing the fields to destroy egg pods are advocated. Nymphs and adults are collected by systematic hand-netting. In Madras, baiting with zinc phosphide or sodium fluorosilicate is adopted. Spraying with Agrocide 0·2 per cent. is suggested in the Punjab. BHC-5 per cent. dust is used in Madhya Pradesh and Mysore with limited success. In Andhra Pradesh, *Oxya* and *Hieroglyphus* are controlled by dusting BHC-10 per cent. Nymphs of *Hieroglyphus* are controlled by dusting with BHC-5 per cent. Studies on the efficacy of different chemicals for the control of these grasshoppers at the Central Rice Research Institute indicated that dusting BHC-5 or 10 per cent. or Aldrin-5 per cent. or spraying Folidol-0·08 per cent. was effective in killing both the adults and nymphs.

LEAF HOPPERS

Trapping adults at lights, or hand netting or sweeping adults and nymphs after spreading a film of Kerosene oil over irrigation water is a common practice in some of the States.

Studies on the seasonal abundance of jassids and fulgorids at Central Rice Research Institute indicated that infestation was very severe on a young crop in ill-drained plots. Hot and humid conditions with temperatures 28° to 28.7°C and humidity 85.4 to 89.6 per cent. were found favourable for the incidence of the pests and their rapid multiplication. In Madras, *Nephotettix* is reported to be extremely severe in tracts where rice is grown under well irrigation. In Andhra Pradesh, it is reported that *Nilaparvata,* which was a minor pest, has become a serious pest due to intensive cultivation.

In Madras and Andhra Pradesh this pest is controlled by dusting BHC-5 per cent. or DDT-5 per cent. or spraying DDT-0.2 per cent. In Mysore, spraying Folidol-0.025 per cent. is recommended. At the Central Rice Research Institute, spraying 'Folidol'-0.025 per cent. or dusting Aldrin, BHC or DDT-5 per cent. is found effective. It has been found that in addition to the insecticidal treatment, draining out the affected plots, letting in fresh water to flow and applying ammonium sulphate as topdressing at the rate of 10 to 20 lb. nitrogen per acre help the crop recover from the ill-effects of hopper damage.

Studies on varietal reaction to *Nilaparvata* indicated that *GEB. 24, Vankisannam* and *Ramgada* were not affected in Andhra Pradesh. At the Central Rice Research Institute, the following Chinese varieties were severely attacked by *Nilaparvata*: *Ch. 2, Ch. 41, Ch. 42, Ch. 43, Ch. 45, Ch. 47, Ch. 62* and *Ch. 63,* while in the same plot *Adt. 20, N. 136, Ptb. 10, B-76-1, Adt. 4* and *Benibhog,* showed very little infestation (Israel and Rao, 1954).

CASEWORMS

Dislodging larval and pupal cases over a film of kerosene oil in irrigation water and attracting moths at lights are recommended in Mysore, Madras, Andhra Pradesh and Orissa. Regarding chemical methods of control, in Mysore, dusting BHC-5 per cent. or spraying Folidol 0.05 per cent. at the earhead stage is recommended. In Andhra Pradesh, dusting BHC-5 or 10 per cent., and in Bihar, spraying DDT emulsion were found effective. The caseworm was effectively controlled at the Central Rice Research Institute by spraying Folidol-0.08 per cent. Water from the sprayed plots should not be drained off for 24 hours after spraying to kill the floating larvae.

LEAF ROLLERS

Cutting off the folded or rolled leaves, disturbing the leaf rolls by dragging a twisted rope or thorny branches and killing the larvae over a film of kerosene oil in irrigation water are recommended in Andhra Pradesh, Mysore and Madras. In Mysore, dusting DDT-5 per cent. is also recommended. Dusting BHC-5 per cent. was found effective in reducing the incidence in Madras and Kerala. At the Central Rice Research Institute, Folidol-0.08 to 0.1 per cent. is found to be very effective in controlling the larvae (Israel *et al.,* 1955).

THRIPS

Thrips are reported to be serious in Hyderabad (Andhra Pradesh), only when the fields are not well manured and there is insufficient water in the field. Dragging

a kerosenated rope over the affected plants is practised in Assam. Nicotine sulphate at the rate of one ounce in eight gallons of water or Endrin at the rate of two to three cc. per gallon of water or BHC-5 per cent. dust are recommended for control in Andhra Pradesh. In Mysore, spraying 0.025 per cent. Folidol is recommended. Trials for the control of thrips at the Central Rice Research Institute have indicated that spraying Pyrocolloid at the rate of one ounce in two gallons gave a satisfactory control, but a very effective control was obtained by spraying Endrin-0.02 per cent. or Folidol-0.04 per cent.

MEALY BUGS

Uprooting affected plants and destroying them is the common method in vogue. Exploratory trials with BHC or DDT have not been entirely satisfactory, as the bugs remain concealed inside the leaf-sheath. Spraying affected patches of crop with Parathion-0.2 per cent., BHC-0.4 per cent., Schradan-0.75 per cent., HETP-0.4 per cent. and DDT-0.4 per cent. indicated promising results in Madras (Santhanaraman, 1952). Experiments conducted at the Central Rice Research Institute showed that spraying Folidol-0.08 per cent. effectively reduced mealy bug infestation.

ROOT APHIDS

Root aphids are controlled by spraying Folidol-0.1 per cent. on the affected plants and on the soil around the plants. Dipping seedlings in 0.08 to 0.1 per cent. Folidol prior to transplanting was found to be an effective prophylactic measure (Israel and Rao, 1955).

CRABS

Crabs are handpicked or trapped in earthen pots by baits. In Bombay, baits of boiled rice mixed with 50 per cent. DDT powder placed at the rate of 1/8 ounce per burrow gave a control of 79 to 82 per cent. A solution of 0.02 to 0.1 per cent. Ethyl Parathion when poured into burrows at the rate of one ounce per burrow, reduced the incidence by 66 to 72 per cent. (Patel *et al.*, 1955). In Andhra Pradesh, crabs are controlled by poison-baiting with Warfarin-0.025 per cent. in popped rice.

Fumigation of crab holes with Cyanogas dust is the control measure generally recommended in the different States.

SNAILS

In Andhra Pradesh, the use of deterrents and hand-picking were found unsatisfactory for the control of snails but draining off water, to the extent possible, and dusting BHC-5 per cent. were found effective (Thirumala Rao, *et al.*, 1953). At the Central Rice Research Institute, mixing Folidol in irrigation water (extreme care should be taken while draining off the water) proved effective in controlling snails.

RATS

Mechanical methods like bow-trapping, digging and catching by professional rat-catchers are practised in Andhra Pradesh and Madras. Baiting with poisons

like Antu, zinc phosphide, Dethmor, and Warfarin is tried in various States with considerable success. In Andhra Pradesh, effective control is brought about with one or two rounds of zinc phosphide baits followed by Warfarin baits. Fumigation of rat-holes with Cyanogas 'A' dust is by far the most effective method of control.

PESTS OF STORED PADDY AND RICE

Experiments have shown that the rice weevil and the rice moth start infesting the developing grain in the field, and reach the store along with the harvested grain, where under favourable conditions they multiply (Pruthi and Singh 1950; Israel and Veda Moorthy, 1956). It is, therefore, essential that the freshly harvested grain is thoroughly dried to eliminate the initial population of insects and reduce the moisture content of the grain. Fumigation with Killoptera or Chlorosol at the rate of 4 lb. per 100 maunds (one maund=82 lb.) of grain before stocking further eliminates the infestation from the field (Narayanan, 1953 b ; Padmanabhan and Israel, 1956).

Though the grain is fumigated before storing, stocks are subject to fresh infestation during the monsoon when the ecological conditions are favourable for fresh infestation. Infestation at this stage is controlled either by dusting 4 per cent. BHC or 5 per cent. DDT on the surface of the bags at the rate of 1 lb. per 100 sq. ft. Grain stocked as bulk is controlled by fumigation with Killoptera or Chlorosol under an air proof cloth at the dosage mentioned above. Grain which is set apart for seed purposes can be stored by mixing either BHC or DDT at the rate of 2 oz. per 125 lb. of grain, without affecting the viability.

Studies undertaken at the Central Rice Research Institute to find out an indigenous insecticide which would be safe to handle, non-toxic to human beings, yet possessing the requisite toxic property to ensure foodstuffs free from insect infestation, showed that the powder of the rhizome of *Acorus calamus* (*Aroidae*), popularly known as 'Sweet flag', meets the purpose. The dried rhizome of 'Sweet flag' was found to possess both the killing and deterrent effects. Mixing 'Sweet flag' powder at the rate of 1 lb. in 100 lb. of either paddy or rice was more effective than dusting either BHC or DDT (Israel and Veda Moorthy, 1953). The grain thus treated did not leave any unpleasant odour in the cooked rice. *Acorus calamus* is, at present, cultivated in limited areas and is not available for extensive use.

Though rice is usually stored unhusked, large stocks are also stored after milling. Milled rice is available as raw or parboiled, and in different grades of polishing. Recent investigations at the Central Rice Research Institute have showed that raw rice is more susceptible to insect damage than parboiled rice, and within the different grades of rice, shelled rice is more susceptible than either single or double polished rice.

CHAPTER 18

SEED MULTIPLICATION AND DISTRIBUTION

The impact of breeding improved strains on the country's production can be felt only if these strains are widely cultivated and cover large areas. This can be achieved only through a well-organized system of multiplication and distribution of pure, high quality seeds of the improved strains. In India, as has been stated elsewhere, 455 improved strains, giving about 10 to 20 per cent. higher yield than the local varieties, have been evolved and released in different parts of the country. The spread of these strains all over the rice-growing areas would bring about a substantial increase in the annual rice production in the country.

Unlike Western countries, where seed-multiplication as well as distribution is a private enterprise and the Governmental agency is only for testing and certifying to purity, viability, etc., of the seed, there are in general no professional seedsmen in India and the work of seed-multiplication and distribution is the responsibility of the State Governments.

In India, the system of seed-multiplication and distribution is basically the same throughout the country, with slight modifications to suit local conditions in different States. The nucleus seed of the improved strains is multiplied on the research stations and Government seed farms and given to selected progressive cultivators called 'A' class or 'Primary' seed-growers for the next stage of its multiplication. The seed obtained from these growers, called 'A' seed or 'Primary' seed, is further multiplied by 'B' class or 'Secondary' seed-growers, and the seed obtained from them is then distributed for general cultivation. The 'A' and 'B' class seed-growers agree to multiply the seed of improved strains on their land under the supervision and guidance of Agricultural Extension staff or Seed Development staff, who attend to the roguing of crop, inspect seed at sowing, harvesting, threshing, bagging and storage, so as to maintain a high level of purity of the seed. The seed-growers agree to sell back the seed to the Department and as an inducement to the growers to multiply seed of high purity, they are offered a premium of six annas to two rupees per maund (82 lb.) of seed sold to the Department. In certain States, they also get preferential treatment in the matter of grant of loans for sinking wells or buying oil engines, and securing the aid of the Plant Protection Services, etc. Only seed of high purity and viability is procured from these growers, and for this purpose, the Agricultural staff thoroughly test the seed before buying the same.

ASSAM

In this State, the nucleus seed of the improved strains is multiplied at four Primary and five District Seed Farms of the Government. The seed so obtained is called the 'Primary Seed', and is taken over by the District Extension staff, who arrange for its further multiplication by 'A' class growers. The 'A' class seed is

purchased back from the grower by the Department at a certain premium over the market rate, and distributed to general cultivators, sometimes at concessional rates.

ANDHRA PRADESH

In this State, a special Seed Development Scheme has been in operation since 1949 under the control of a Seed Development Officer, who acts as a liaison officer between the research stations and the District Agricultural (Extension) Officers, and exercises an overall supervision on the primary and secondary stages of multiplication and distribution of the seed. The nucleus seed from the research stations is multiplied on the cultivators' holdings, called 'Primary' and 'Secondary' seed farms. An agreement is entered into with the Primary and Secondary seed farm owners to multiply the seed under the supervision of the Agricultural Staff, and to sell back to the Department an agreed quantity of not less than 4 to 6 bags (656-984 lb.) of seed per acre. The seed procured from 'Primary' seed-growers has to be of 97 per cent. purity and 95 per cent. viability. Supervision at the primary stage is the direct concern of the Seed Development staff, while that at the secondary stage is carried out by the Extension staff.

The targets under Seed Farm areas and seed to be procured during 1955-56 and 1956-57 are given below.

	Year	Area in acres	Seed to be procured (in tons)
Primary Seed Farm	1955-56	4,755	2,194
	1956-57	6,409	2,789
Secondary Seed Farm	1955-56	15,105	6,959
	1956-57	13,907	5,762
Total ..	1955-56	19,860	9,153
	1956-57	20,316	8,551

In Hyderabad, a greater part of which has been merged with Andhra Pradesh on the reorganization of States in 1956, the multiplication and distribution of improved strains are carried out, since 1950, under a separate scheme, called the 'Paddy Seed Multiplication and Distribution Scheme'. According to this Scheme, the Rice Specialist raises nucleus seed of all improved varieties on an area of 20 acres reserved for the purpose. The nucleus seed is then multiplied on the Government farms, both in the *abi* and *tabi* seasons. The purity and viability of the seed produced is maintained at 98 per cent. The seed produced at the farms is allotted to various districts for further multiplication by 'A' and 'B' class growers. The number of strains and the quantity of seed of each strain to be multiplied by a district depend on the season and the availability of water in the area. The seed-growers multiply the seed under certain conditions, *viz.*, (a) they must sell a part or whole of the produce to the Government at a premium of Re. 1 per maund (82 lb.); (b) they may be exempted from payment of 'levy' to the Government to the extent of the seed supplied to the Department; (c) they have to arrange

for a thorough roguing of the crop under the direct supervision of the Extension worker or workers of the zone. Besides the payment of premium on the seed sold, the seed-farmers usually get preference in the grant of loans for the purchase of oil engines, sinking and repairing of wells, securing Plant Protection Services, etc.

The seed from 'B' class growers is further multiplied by 'C' class growers. Usually, the produce of the 'C' class growers is not procured. But under exceptional cases, when the seed is of high purity, it is procured for further distribution, more or less on the same conditions as in the case of 'A' and 'B' class growers. The grades of purity for 'A', 'B' and 'C' class growers are usually 98 to 100, 92 to 99 and 87 to 95 per cent., respectively.

The seed of all classes of growers is stored in the permanent Departmental godowns, which serve as supplying centres and are generally located at the headquarters of the Agricultural Assistants. The stocks from here are shifted to temporary seasonal godowns at the headquarters of the fieldmen in the interior villages, for distribution to cultivators.

The Hyderabad Seeds and Seedling Act, No. XXVIII, passed in 1951, enjoins on cultivators to grow only seed of improved varieties recommended for a particular area. The Agricultural workers bring the existence of this Act to the notice of the cultivators, and use moral persuasion for its enforcement.

During the 1955-56 season, 295.3 acres of land were grown for multiplication of nucleus seed on seven Government Farms, and 243 tons of seed were produced. During the same year, about 3,266 tons of seed of improved strains were distributed among the cultivators.

BIHAR

In this State, the nucleus seed supplied by the research stations is multiplied on departmental farms. The pedigree seed from these farms is grown by 'A' class registered growers for multiplication in the National Extension Service and Community Development Blocks. The programme of distribution of seeds from 'A' to 'B' class growers in each National Extension Service and Community Development Block is carried out by sale or exchange. The quantity of seed multiplied at the various stages is given below.

Nucleus seed production at Research Stations (tons)	Pedigree seed from Farms (tons)	Seed produced by 'A' Class growers (tons)
55	232	1,100-1,460

The State expects to cover 75 per cent. of the area under rice with seeds of improved strains by the end of the Second Five Year Plan (1960-61).

BOMBAY

Since 1945, a regular nucleus seed scheme is in progress in the State. The nucleus seed of improved strains thus produced is supplied to the Agricultural Extension staff, who multiply the same in various stages on the fields of registered seed-growers, and then distribute the same to the cultivators.

KERALA

The nucleus seed from the research stations is multiplied in two stages on the lands of registered growers, and then distributed to cultivators.

MADHYA PRADESH

In this State, 69,600 tons of seed of improved varieties, sufficient to sow 1.55 million acres, have so far been distributed; this covers about 16.6 per cent. of the area under rice.

MADRAS

The system of seed-multiplication and distribution of the improved strains is more or less similar to that of Andhra Pradesh. A consolidated indent for seed is sent by the District Agricultural Officers to the Paddy Specialist, who is the central authority for rice seed distribution. Annually, 200 to 250 tons of nucleus seed, to cover 15,000 to 16,000 acres of primary seed farms, are produced. The seed is multiplied on primary and secondary seed farms, the owners of which are paid a premium for the seed sold back to the Department. Seed procured from secondary farms is distributed for generalcultivation.

A new system, called the 'Village Seed Farm Scheme,' has been introduced recently. According to this Scheme, the primary seed is distributed at the rate of one pound per acre of rice in the village to selected influential cultivators through village associations, and multiplied in these village seed farms. Since one pound of seed multiplies itself approximately 50 times, the entire rice area in the village is covered by improved strains in the following years, through distribution or exchange with other cultivators. During the first year (1954-55) of the working of the Scheme, 6,400 villages out of a total of 20,000 in the State were benefited, and at present, 10,000 villages are covered by the Scheme. This Scheme has been found to be a great advance on the old method of seed multiplication and distribution in extending the area under improved strains.

In order to supply enough nucleus seed for the successful execution of the Scheme, 400 new State Seed Farms for multiplication of nucleus seed are proposed to be started in the first three years of the Second Five Year Plan.

Seed Development Officers have been appointed in the major rice areas in the State for effective supervision of the multiplication of seed, the maintenance of its purity and its rapid spread.

ORISSA

In this State, pedigree seed of the improved strains is grown at the three Rice Research Stations, Bhubaneswar, Berhampur and Jeypore, and the nucleus seed multiplied at the Government Seed Farms and Demonstration Farms. Thus about 700 tons of nucleus seed are produced from about 1,000 acres of land. The nucleus seed is further multiplied by 'A' class registered growers under the guidance and supervision of the Agricultural Department. The registered seed grower undertakes to supply at least 10 times the quantity of seed taken by him. In return, he is paid a premium of rupee one per maund (82 lb.). As a matter of policy no registered seed grower is given more than one or two improved varieties for multi-

plication. On the average there are about 150 registered seed-growers in each district, who on an average, supply about 1,300 tons of improved seed to State Agricultural Department for distribution. It is estimated that ten per cent. of the area under rice is covered by improved seeds and it is proposed to raise this coverage to 40 per cent. through the integration of the *Gram Panchayats* and National Extension Blocks.

PUNJAB

In this State, about 9 to 11 tons of nucleus seed of improved varieties are raised on the two rice research stations every year. This seed is further multiplied in one or two stages by the Deputy Directors of Agriculture on the lands of progressive growers. The seed is purchased from the growers at the premium of six annas per maund. In this way, 110 tons of seed of improved strains become available every year, which can cover an area of about 9,000 acres. In the Second Five-Year Plan, it is proposed to establish 182 seed farms of 25 acres each, for the multiplication of nucleus seed of improved strains of various crops, including rice, and it is expected that by the end of the Second Five-Year Plan in 1960-61, the entire area under rice in the State will be covered by improved strains.

UTTAR PRADESH

In this State, the nucleus seed from the main research station is multiplied at the Government Seed Farms. The seed obtained from these Farms is then supplied to the 'Improved Seed Stores', which issue it to interested seed-growers for further multiplication under the supervision of the district agricultural staff, on the understanding that the entire produce, if required, will be made available to the Department. Distribution of seed to the cultivators is done through a network of co-operative seed stores, spread all over the State. These stores are fed by the Improved Seed Stores of the Agricultural Department. The seed is distributed to the cultivator on *sawai* basis, under which the cultivator returns 25 per cent. more in kind at the time of harvest and also agrees to sell the seed to the Government, if required to do so.

WEST BENGAL

In this State, there are 18 seed multiplication farms, including the research stations. These farms cover an area of 2,300 acres, and are capable of producing 733 tons of the nucleus seed. It has been proposed to open 200 new seed farms of 25 acres each, capable of producing 2,418 tons of nucleus seed every year. An additional 513 tons of nucleus seed is proposed to be raised on the fields of certain reliable 'A' class seed-growers, thus obtaining a total of 3,663 tons of nucleus seed. It is anticipated that there will be an additional production of 3,663 tons of nucleus seed as a direct result of the demonstration and propaganda through the well-developed Extension organisation. Thus, an area of 0.53 million acres is expected to be covered yearly by the nucleus seed. This seed is expected to be further multiplied, partly through registered seed-growers, and partly through growing on five-acre demonstration farms on cultivators' holdings. In the first case, the registered grower is expected to be paid a premium of Rs. 2 per maund over the

market price for the produce procured by the Department. In the latter case, the Government is to pay 50 per cent. of the cost towards purchase of seeds, fertilizers, manures, implements, etc. in the first year, and 25 per cent. of the cost in the second year. An adequate number of seed godowns is expected to be built so that seeds procured may be stored properly.

CHAPTER 19

PRODUCTION AND DISTRIBUTION OF FERTILIZERS

Effective research and large-scale demonstrations have been undertaken in this country on the use of fertilizers to increase production, and Extension Workers of the State Departments of Agriculture, Community Development and National Extension Service Centres, all carry to the farmer results of the recommendations emanating from experimental stations. Simple trials in cultivators' fields are also laid out to demonstrate the benefit of fertilizers under different soil and climate conditions. As a result of all these, rice farmers in the country are getting fertilizer-minded. The available consumption figures for different fertilizers relate to all crops in the country. It is, therefore, difficult to get an exact estimate of the amount of fertilizers used in rice production alone, but it may be safely assumed that the consumption in this sector has been quite high, particularly during the recent years when the drive for Japanese method of Rice cultivation was launched. Farmers have seen the benefit of the fertilizer use and the consumption of fertilizers for rice production is, therefore, on the increase.

Prior to 1947, the country produced only a fraction of the total quantity of fertilizers consumed, but during the last few years, fertilizer production has increased tremendously, and the demand for fertilizers has far exceeded local production. Among the various kinds of fertilizers used in the country, sulphate of ammonia and superphosphate are the two principal fertilizers. The increasing demand for these fertilizers and their need for achieving the food targets fixed by the Government in the Second Five Year Plan call for an increased output in the country, and an expansion of the local production is contemplated.

The following recommendations in Table 71 have been made by the Standing Committee on Fertilizers and Manures, Ministry of Food and Agriculture, Government of India, regarding fertilizer consumption targets for the remaining three years of the Second Five Year Plan.

TABLE 71. TARGETS FOR CONSUMPTION OF DIFFERENT PLANT NUTRIENTS (TONS)*

Year	Nitrogen	Phosphoric acid	Potash
1958-59	300,000	80,000	25,000
1959-60	400,000	120,000	35,000
1960-61	500,000	150,000	45,000

* *Fertilizer News*, 1958, **3** (3) : 7

NITROGENOUS FERTILIZERS

The principal nitrogenous fertilizers manufactured in the country is ammonium sulphate. The consumption of this fertilizer has considerably increased in the

last few years, but the local production in the country has lagged far behind demand, and appreciable quantities of the fertilizer are imported from abroad to cover the deficit. The Government, realising the importance of this fertilizer, have established a large state-owned nitrogen fixation plant at Sindri, with a rated capacity of 1,000 tons of ammonium sulphate per day. There is at present a total annual installed capacity for the production of 426,890 tons of ammonium sulphate in the country. The actual production and consumption figures since 1954 for ammonium sulphate, as given in *Fertilizer News*, 1957, **2** (5) :12 are given in Table 72.

TABLE 72. PRODUCTION AND CONSUMPTION OF AMMONIUM SULPHATE SINCE 1954.

Year	Actual production (tons)	Consumption (tons)
1954	337,175	452,972
1955	389,887	499,087
1956	381,887 (Estimated)	—

With the fast increasing demand on the use of nitrogenous fertilizers and with the increased targets of food production during the Second Five Year Plan, it has been estimated that the country will need a total of 500,000 tons of nitrogen, equivalent to 2.5 million tons of sulphate of ammonia by 1960-61. The expansion of the existing state-owned enterprise at Sindri has been undertaken to produce urea and sulphate-nitrate fertilizers in addition to sulphate of ammonia. The FACT factory at Alwaye, in Kerala, also proposes to increase the output of ammonium sulphate during the Second Five Year Plan period. Three more fertilizer factories at Bhakra-Nangal in the Punjab, Rourkela in Orissa, and Neyveli in south India, are also likely to go into production duringthe Second Five Year Plan period. The principal nitrogenous fertilizers to be manufactured in these factories will be calcium-ammonium nitrate and urea.

PHOSPHATIC FERTILIZERS

Superphosphate of lime is the only phosphatic fertilizer, at present, manufactured on large scale in the country, and the total installed capacity of this fertilizer up to 1957 was about 3,11,000 tons per year. Recently, a new factory, with installed capacity of 60,000 tons per year, has gone into production at Sindri. Actual production and consumption of this fertilizer since 1954 are given in Table 73 (*Fertilizer News*, **2**:14, 1957 ; **3**:13, 1958 ; **3**:16, 1958).

The Government have been making efforts to popularise and encourage the use of this fertilizer and have been giving for some years, a subsidy up to 25 per cent. of the total cost. This subsidy is shared equally between the Central and State Governments. With a view to popularising the use of superphosphate, zonal councils for different regions are being established. The councils will consider the special problems of each region with local officials, and decide on the ways and means to increase the consumption of this fertilizer The work of various zonal

TABLE 73. PRODUCTION AND CONSUMPTION OF SUPERPHOSPHATE SINCE 1954

Year	Installed capacity (tons/year)	Actual production (tons/year)	Estimated consumption (tons/year)
1954	216,000	108,000	92,436
1955	270,000	78,000	80,075
1956	270,000	83,000	97,648
1957	311,000	146,000	134,848

councils will be co-ordinated by a central council under the Ministry of Food and Agriculture of the Government of India.

It has been estimated that by 1961, the requirements of phosphoric acid in the country to meet the demand for increased food production, will be about 150,000 tons, which is equivalent to about 900,000 tons of superphosphate. Thus, the installed capacity will have to be increased nearly three-fold to meet the requirements. This expansion is taking place both in the public and private sectors, and a number of factories at various locations are likely to spring up during the Second Five Year Plan period. The manufacture of double and triple superphosphates, ammonium phosphate and di-calcium phosphate is also contemplated.

MIXED FERTILIZERS

Many manufacturers in the country prepare mixed fertilizers, and modern mixing equipment has been provided in some fertilizer plants. The production of mixed fertilizers was nearly 200,000 tons during 1954. Manufacturers of fertilizer mixtures obtain their supplies of ammonium sulphate through Government and other sources in the open market.

POTASH

Potash as plant food has received little attention, as most of the soils in the country are considered well-supplied with available potash. With new targets of increased food production during the Second Five Year Plan period, and with the increased use of nitrogen and phosphoric acid, the need for potash as plant food may arise. At present, most of the potash required in the country is imported, and only small quantities are produced locally.

FUTURE PROGRAMME

Distribution of chemical fertilizers has been regulated by the Central Government under the 'Central Fertilizer Pool,' a state-trading scheme operating since 1943-44. Distribution of both sulphate of ammonia and superphosphate was originally under the Scheme, but during August 1952, the phosphate part of the Pool was discontinued. The object of the Pool has been to ensure an equitable distribution of the available supplies at the minimum possible price, and thus popularise the use of the fertilizer for increasing agricultural production. This

Scheme operates on a 'no profit and no loss' basis, and under the Scheme, the entire local production of sulphate of ammonia is purchased by the Central Pool, and imports to meet the deficit in the country are made on Government account. Pooled supplies are then distributed at a uniform rate per ton to State Governments and certain bulk consumers. The price includes the freight for delivery at the railway station indicated by the allottee. The Central Government also fixes the ceiling price and the State Governments are required to make the distribution arrangements in such a way as to cover the incidental and transport charges within the State, so that cost to the consumer does not exceed the ceiling price fixed by the Government. During 1957, Government fixed the pooled price at Rs. 350 per ton delivered at rail-heads and ceiling price covering all incidental charges was fixed at Rs. 380 per ton. Some of the State Governments are given special subsidies to sell the fertilizer at a uniform rate, because of the transport difficulties in the areas. The uniform price has been fixed by the Government because of the difference in production costs in the various factories, and also of that of the imported fertilizer.

The distribution of fertilizers to cultivators within the State is managed by State Governments, either through the agency of co-operatives, or through private dealers. Some States distribute the fertilizer through Government sales depots also. The approved organisations appointed by the State Governments maintain a network of sub-agencies and depots at a number of locations in the State to serve the needs of the farmers in the area. During the past many years there has been a general improvement in the retail distribution arrangements in the States, and the number of depots has increased.

The States have also been advised by the Central Government to take the following steps to ensure an improvement in their distribution system.

1. To explore the possibilities of utilizing the *panchayats*, Community Project areas, National Extension Blocks and co-operative organizations and other developmental agencies for the distribution of fertilizers and also for the propagation of its use.

2. To maintain buffer stocks at different points in the State, so that the cultivators can obtain a guaranteed supply of fertilizers with the least difficulty.

3. To increase the number of depots so that the cultivator has not to travel more than five miles to obtain his supply of fertilizers.

4. To ensure that all depots have enough stocks at all times to meet the local demand for fertilizers.

The States are also advised to indent stocks far in advance in the lean months so that the transport difficulties met within the peak season are avoided.

The distribution of superphosphate, after it was taken off the Central Pool, is handled by private enterprisers, who appoint their own agents for an effective distribution of the material. The fertilizer mixture manufacturers also distribute their produce through private channels.

In spite of these distribution and price facilities offered by Government, the cultivator invariably finds it difficult to purchase the fertilizer against cash payment, because the same is not readily available with him. The cultivator is mostly in need of credit, and the State Governments realising the necessity for this have, since 1953, started granting loans to cultivators for the purchase of chemical fertilizers.

These loans are realised in cash or in kind at the end of the crop season. The grant of loans has since been continued and ways and means of advancing and recovering loans have been improved. Most of the States advance loans for the purchase of sulphate of ammonia only, the material that is handled by the State or its appointed agencies. Some States also encourage the sale and distribution of bonemeal and other phosphatic fertilizers by the grant of special subsidies.

In areas where the practice of using fertilizer has been in vogue for a long time, the commodity is easily available through established agency depots. In the interior of the country, however, where fertilizer use is progressing rapidly now, State Governments are taking steps to get more depots and sub-depots opened, so that the fertilizer is readily available to the cultivator.

Apart from popularizing the use of the commercial fertilizers, State Governments also encourage the use of bulky organic manures and green manures. The practice of compost-making in rural areas is being popularized, and the growing of green manures is encouraged. For encouraging the latter the State Departments of Agriculture take steps to make the seed of green manure crops available to cultivators in local areas.

CHAPTER 20

ORGANIZATION AND WORKING OF PLANT PROTECTION

Till recently, plant protection work was undertaken by the Extension staff of the States along with propaganda, distribution of seed, fertilizers, etc. In view of the importance of plant protection in the country, it was felt that this work should be separated and entrusted to a special wholetime staff, and consequently, in 1946, the Directorate of Plant Protection and Quarantine was set up by the Government of India, and separate plant protection staff were also appointed in the States.

The Directorate of Plant Protection, Quarantine and Storage of the Government of India is planning to establish a chain of 14 plant protection centres in different parts of the country. Six of these centres have already been established at New Delhi, Palanpur, Indore, Hyderabad, Tiruchirapally and Ernakulam, and four others are in the course of being established at other places. Under the Second Five Year Plan, provision has been made for strengthening these ten centres, and adding four more to their number. The functions of these plant protection centres are to provide the State Governments with pesticides, fungicides and plant protection equipment in times of pest and disease outbreaks, and to assist them also with technical and other personnel in control compaigns, pest and disease surveys, evaluation of the results of plant protection operations, etc. The centres are also intended to organize training programmes in plant protection on a regional basis.

The pattern of plant protection organization is not exactly the same in all the States. In some, as for example in Uttar Pradesh and the Punjab, the whole organization is technically and administratively under the control of the State Entomologist, who is also in charge of entomological research, and who avails of the advice of his colleague, the State Plant Pathologist, about the control of plant diseases. In some others, *e.g.*, Bihar, Madras, and Andhra, the plant protection organization is under the charge of a Plant Protection Officer or several such officers responsible to the State Director of Agriculture or his Deputy. In such cases, the State Entomologist and the State Plant Pathologist provide technical advice and guidance for the control of pests and diseases, respectively. In Assam, the plant protection organization is under the control of the State Plant Pathologist. All plant protection organizations have staff initially trained in agricultural entomology or plant pathology. Most of the States have established centres or sub-centres, where the plant protection staff and equipment are placed for convenience of approach and operations. In addition to the regular plant protection organizations, some States have had at times special schemes for the control of rats, jackals, monkies, weeds, etc.

An interesting development has been the constitution of a Plant Protection Board composed of the representatives of Himachal Pradesh, the Punjab and Kashmir, at the initiative from these States. The function of the Board is to meet periodically, and discuss common problems of pest and disease control, with a view

TABLE 74. ACREAGE COVERED BY RICE SEEDS TREATED WITH FUNGICIDE AGAINST SEED BORNE DISEASES, BY SPRAYING AND DUSTING FUNGICIDE AND INSECTICIDE FOR CONTROL OF RICE DISEASES AND PESTS IN DIFFERENT STATES IN INDIA DURING 1951 TO 1955 (PRIOR TO REORGANIZATION OF STATES)

	Year	Assam	Andhra	Bihar	Bombay	Coorg	Hyderabad	Madras	Mysore	Orissa	Uttar Pradesh	West Bengal
Area in acres covered by seeds treated with organo-mercurial Fungicide against seed-borne diseases of rice during 1951-1955	1951	—	—	—	—	2,886	442	1,37,665	6	1,216	153	51,313
	1952	—	—	1,500	—	1,399	292	98,537	—	7,658	—	8,369
	1953	—	2,749	3,100	—	806	7,487	76,671	238	8,923	1,609	10,000
	1954	—	21,956	5,465	—	2,850	1,256	32,960	1,120	108	1,664	8,936
	1955	—	76,071	20,000	—	1,010	1,395	22,277	5,320	10,522	434	37,517
Area in acres covered by spraying (copper fungicide) and dusting (sulphur) against diseases of rice during 1951-55.	1951	—	10	—	—	372	35	3,905	625	—	—	—
	1952	—	—	—	—	—	6	7,321	1,388	5,490	—	—
	1953	—	313	—	1,500	140	44	4,260	592	312	—	—
	1954	—	1,132	—	—	970	785	6,130	—	—	—	—
	1955	—	1,325	—	—	487	215	3,333	—	2,768	—	—
Area in acres covered by spraying and dusting (5 per cent. BHC or DDT, 'Endrin', 'Pyrocolloid' and 'Folidol') against pests of rice during 1951-1955	1951	7,929	—	800	—	758	11,465	5,764	1,700	6,609	380	31,019
	1952	6,389	—	1,855	804	708	17,190	23,807	104	2,020	99	33,817
	1953	13,463	—	1,848	1,539	3,579	1,784	7,622	72	19,966	154	99,013
	1954	—	89	1,796	23	,255	1,051	44,049	973	—	712	65,122
	1955	—	2,467	3,077	—	1,923	320	32,913	1,621	—	464	35,356
Area in acres treated against *Chara* spp. (a weed) with copper sulphate during 1951-1955	1951	—	—	—	—	—	—	—	—	—	—	12,824
	1952	—	—	—	—	—	—	—	—	—	—	18,476
	1953	—	—	—	—	—	—	—	—	—	—	30,000
	1954	—	—	—	—	—	—	—	—	—	—	687
	1955	—	—	—	—	—	—	—	—	—	—	7,454

Data for Assam, Bihar and West Bengal were obtained directly from the respective State Departments of Agriculture.

Data for other States were obtained through the courtesy of the Directorate of Plant Protection, Quarantine and Storage, New Delhi.

to devising or initiating concerted measures simultaneously in the respective areas of these States.

Plant protection organizations under the Government of India and in the States, even though they engage in large-scale control campaigns in the countryside, are in essence technical organizations, and inadequate in man-power and resources to reach every one of the 5,58,089 villages that constitute the backbone of Indian economy. By and large, they can be expected only to show the way, leaving others to follow up with sustained and extensive efforts. This latter role has been taken over by the Community Projects and National Extension Service Blocks, which include plant protection in their various activities. These organizations have taken steps to ensure that their workers receive some training in plant protection, and are in a position to assist the cultivators in adopting the necessary measures against pests and diseases. The work is carried on in close collaboration with the State plant protection organizations.

The Government of India also provide assistance for plant protection work under a scheme by which they share with the State Government the difference between the cost of pesticides and the subsidised rate at which they may be supplied to the cultivators, and bear 50 per cent. of the cost of hand-dusting and spraying machines purchased by a cultivator.

WORKING

For field control, trained technicians are posted in groups of villages, who bring to the notice of the villagers any outbreak of pests and diseases in a locality and immediately organize control operations with the help of the cultivators. The information is also transmitted to the higher authorities in the *thana* or sub-divisions, and to the Plant Protection Officers at the Headquarters. Sufficient equipment and a small supply of chemicals are generally available locally. If more are needed, the district organization speedily arranges for the supply of the same.

In Madras State, the transmission of the news about pests and diseases is given the highest priority. Weekly forecasts of pests and disease outbreaks are transmitted through the radio, newspapers and other Governmental agencies, on the basis of regular information supplied by the Extension staff.

Control of Locusts. The locust is not a specialized rice pest like the stem borer and the gall fly, but in view of its omnivorous habit, rice does not escape its ravages. The control of locusts, therefore, has significance for the rice crop. In India, the breeding centres of locusts are situated in the arid western desert region, from where they migrate to the cultivated regions lying to the east of their breeding ground. In such migrations, locust swarms have been seen as far east as Bengal.

The Government of India are directly responsible for locust control in the desert areas, covering a total of about 81,000 square miles and lying in the States of Rajasthan, Bombay and the Punjab. Locust control in other areas called 'cultivated areas' for convenience of reference, is the responsibility of the State Governments concerned.

Under the Indo-Iranian Anti-Locust Convention, the representatives of the two Governments periodically meet and discuss common problems in locust control. A similar understanding exists between the Governments of India and Pakistan.

India has also been collaborating with the Food and Agriculture Organization of the United Nations in the matter of locust control.

Control of Pests and Diseases of Rice. Treatment of rice seeds prior to sowing with organo-mercurials is a specific remedy against the foot rot of rice. Besides, it is also advocated in some states for the control of the brown spot disease. Increased germination and a better stand could always be expected from seed treatment with fungicides, when slightly unfavourable factors like a cooler temperature and unfavourable moisture for germination exist at sowing time. It also prevents the setback in germination caused by weak seed-borne pathogens under conditions favourable for their attack. Since the cost of treating a maund (82 lb.) of seed is only 5 to 6 annas, it is becoming increasingly popular throughout the country.

The spraying of insecticides is steadily gaining ground in all States for the control of insect outbreaks. The insecticides, Gammexane, BHC, DDT, Folidol and Endrin, are in great demand by cultivators. Plant protection agencies of States as well as private commercial interests have helped in demonstrating their great efficacy in controlling the various pests, and have also made them readily available in quantities wherever required. The synchronisation of spraying with the brood emergence of pests determined through light trap catches is now being advocated, and is likely to be widely adopted in the next few years.

Copper fungicidal sprays to control blast is not very popular, except in Madras, where it is adopted as an emergency measure by cultivators. Much headway has to be made in the early recognition of blast symptoms and timely application of sprays.

The weed *Chara* spp. can be successfully controlled by the application of copper sulphate at the rate of 12 to 15 lb. per acre, depending upon the volume of water (usually, 5 to 8 ppm of copper sulphate is sufficient to bring about the death of *Chara* spp. in 48 hours.).

Copper sulphate is usually applied as such, or mixed with three to four times the quantity of ammonium sulphate. Usually three methods of application of copper sulphate are in vogue:

1. Keeping the copper sulphate suspended in a gunny bag at the place of entry of water into the field.
2. Suspending small muslin or gunny bags containing copper sulphate at different places in the field.
3. Scattering the finely pulverised copper sulphate in the field.

The area covered by control operation in some States during the last few years is given in Table 74.

CHAPTER 21

JAPANESE METHOD OF RICE CULTIVATION

During the last few years, considerable interest has been aroused in India in the 'Japanese method of rice cultivation,' a method which combines improved cultural practices with judicious manuring and proper plant protection measures. This method of rice cultivation has given encouraging results in increasing acre-yields, and is gradually gaining popularity in the country. Ramiah and Vachhani (1950) in an article in *Indian Farming*, pointed out the important features of rice cultivation in Japan largely responsible for the high acre-yields obtained there (an average 3,500 lb. per acre). This article aroused a lot of interest in the country.

Early in 1951, a delegation led by Sri Pran Lal Kapadia was sent to Japan by the Government of Bombay to study the agriculture and cottage industries in that country. Impressed by the high rice-yields obtained in Japan, Sri Kapadia along with Sri Harishchandra Patil contacted Dr. Iwao Kamo, who explained to them the rice cultivation technique practised in Japan, and arranged for a practical demonstration of the method employed. On their return to India, the Japanese method of rice cultivation was tried at the Bombay Government's Agricultural School at Kosbad,[1] Rice Research Station at Karjat (Bombay), and at the Kora Gramodyoga Kendra, Borivli (Bombay), during the year 1952-53. The results were encouraging, and the yield of paddy obtained ranged from 3,804 to 6,000 lb. per acre. It was observed that by judicious manuring and careful cultivation, there was considerable scope for increasing the acre-yield of rice. The President of India was greatly impressed with the results obtained at the Kora Gramodyoga Kendra, and drew the attention of the Union Minister for Agriculture, Dr. Punjabrao Deshmukh, to the Bombay experiments, who then obtained the details of the method and relevant data of the experiments from the State Department of Agriculture, Bombay, and the Kora Gramodyoga Kendra. These results also attracted the attention of the Prime Minister of India, on whose instructions the delegation, which was sent to America to study the extension methods of 1952, was asked to visit Japan on their return journey to acquaint themselves with the technique of rice cultivation practised in that country.

The Union Minister for Agriculture, in a broadcast to the nation on the 10th January, 1953, explained the salient features of the Japanese method of rice cultivation, and initiated a pilot campaign for the adoption and popularization of the method on 15th March, 1953. Since then it has gained popularity, and is being pushed up by the Union Ministery of Food and Agriculture in collaboration with the State Governments.

Salient Features of the Japanese Method. The main features of the Japanese method of rice cultivation are:

1. selection of good and heavy seeds for sowing in the nursery after treatment with a fungicide ;

2. use of low seed-rate (15 to 20 lb. per acre) and sowing thinly in the nursery ;

3. preparation of a well-pulverized, raised and narrow seed-bed ;

4. application of liberal doses of organic and inorganic fertilizers to the nursery ;

5. weeding of nursery beds, and careful uprooting of seedlings ;

6. transplanting of seedlings in lines with a regular spacing of 10 × 10 inches with four seedlings per hill ;

7. heavy manuring of rice fields with organic manures and fertilizers ;

8. frequent interculturing of the crop ;

9. periodical spraying of the crop against diseases and insect pests.

Ramiah (1953b) and Vachhani and Parthasarathy (1954), reviewing the work done on the Japanese method of rice cultivation in India, discussed the importance of its several features as follows.

Seed-bed. The Japanese method advocates a low seed-rate and a thinly sown seed-bed to get strong and sturdy seedlings for transplanting. The local practice is to sow 80 to 100 lb. of seed for a broadcast crop, and 30 to 40 lb. or even more for a transplanted crop.

The selection of heavy seeds by steeping them in salt water is one of the factors advocated under the Japanese method. The advantage of selecting heavier seeds is that they germinate quickly, and the seedlings would be uniform in size at the time of planting.

Raised and narrow seed-beds with channels in-between them provide easy drainage. This is particularly desirable in areas with heavy rainfall as the seedlings are likely to be washed away by excessive rain or in low-lying areas where the seed-bed would be submerged under water.

The seed-bed soil should be well-pulverized and timely weeding of the nursery should be done. In manuring of the seed-bed, emphasis should be more on the organic rather than on the inorganic, as a thick layer of organic manure mixed with the top soil makes it friable and facilitates pulling of seedlings.

Transplanting in Lines and Spacing Between Plants. The spacing and number of seedlings per hill depend on the variety, type of soil and time of planting. In India, bulk-planting is usually done with 4 to 5 seedlings and, in some cases, even 8 to 10 seedlings per hill as in Bombay State. The spacing between the plants varies usually from 6 × 6 to 9×9 inches, depending upon the duration of the variety. The Japanese method advocates planting of seedlings in straight lines with 10 × 10 inches spacing between plants, which helps in easy interculture without any damage to plants. However, for early varieties (120 days or less) a spacing of 10 inches between lines and 4 inches between plants with 3 to 4 seedlings per hill, and for late varieties a spacing of 10 inches between lines and 6 to 8 inches between plants with 2 to 3 seedlings per hill may be the optimum requirement.

Manuring of the Field. The use of more manures and fertilizers is the most important factor connected with the Japanese method, and greatest emphasis has been placed on this. In Japan, very large quantities of manure mixtures are applied, which consist partly of organic and partly of inorganic fertilizers. The latter, on an

average, consists of 60 to 100 lb. of nitrogen, 40 to 60 lb. of phosphoric acid and 30 to 40 lb. of potash per acre. In India, a limited quantity of organic matter is applied, and the inorganic fertilizers have come into vogue only in recent years, and are applied to a very limited extent. Experimental evidence in the country indicates that heavy doses of inorganic fertilizers, as practised in Japan, do not give economic returns. On an average, application of 20 to 60 lb. nitrogen per acre in the form of ammonium sulphate is found to be the optimum in most of the areas, and a higher application results in a low yield response.

Interculturing. The Japanese method of intercultivation not only removes the weeds, but also stirs the soil between plants to a few inches depth, which provides better aeration in the root zone to permit better assimilation of nutrients and promote better tillering. In India, weeding is done once or twice during the season, but no interculturing is given. The number of interculturings will vary from two to five, depending upon the duration of the variety grown. The last interculturing should be before the primordia is formed, i.e., about two weeks before the shot blade stage.

The features of Japanese method of rice cultivation are in no way new to this country, but what is new is the simultaneous application of all improved cultural practices, i.e., proper tillage, low seed-rate, line-sowing, adequate spacing, liberal and judicious use of manures and fertilizers, irrigation and weedings, etc.

The Japanese method of rice cultivation is more beneficial in the areas of assured water supply, but it can also be safely practised with necessary modifications in the drilled rice tracts.

ACHIEVEMENTS

During 1953-54, when a pilot campaign on the Japanese method of rice cultivation was launched for the first time on a country-wide scale, an area of over 400,000 acres was brought under this method. The increased production from this area was estimated at 0.197 million tons of rice, which works out to approximately, 1,100 lb. per acre. To give an incentive to this campaign, the Central Government, apart from the technical advice and guidance, rendered financial assistance to the States.

The campaign was organized on a more systematic way, with a definite target for each State, during 1954-55. The overall target set for the whole country was 2 million acres. In all, an area of 1.32 million acres was brought under the Japanese method. This resulted in an estimated increased production of 0.745 million tons of rice, or approximately 1,300 lb. of additional production of rice per acre. The shortfall in the achievement of the target was due to unprecedented floods on the one hand, and continued drought conditions on the other, in most of the chief rice-growing States.

Encouraged by the results achieved during the preceding years, the campaign for popularization and extension of Japanese method was further intensified and an area of 2.37 million acres was brought under this method during the year, 1956-57. The average yield of rice under the Japanese method during the year worked out to 1,632 lb. per acre as against 1,093 lb. by the local method (Report of the Ministry of Food and Agriculture, 1957-58), thus giving an overall increased pro-

duction of 0.57 million tons of rice. The area under this method is gradually increasing and it is proposed to bring 8 million acres under this method, by the end of the Second Five Year Plan period.

The results achieved in the various States by the adoption of the Japanese method of rice cultivation are presented below.

Assam. Demonstrations on the Japanese method of rice cultivation were given to the cultivators. Certain modifications in respect of seed-bed preparation and seed rate were introduced in the method to suit the climatic conditions of the State, which are characterised by a high humidity and heavy rainfall. It is proposed to bring about 0.5 million acres under the Japanese method by the end of the Second Five Year Plan.

Andhra Pradesh. The Japanese method was introduced in the State during 1953-54, and due to intensive propaganda, it was possible to cover an area of 0.645 million acres under this method during 1956-57. The treatments recommended under the Japanese method were, however, slightly modified to suit local conditions. This method is gaining popularity in places with the lighter type of soils such as loams and sandy loams, which respond to intensive manuring. The additional yield obtained by the adoption of the Japanese method over the local method is estimated at about 719 lb. of grain per acre.

In many places of the Hyderabad portion of the State, the raised seed-bed recommended under the Japanese method was not found useful. So the raising of the seedlings in flat beds, as is the usual practice, is being recommended. The Japanese method has gained the greatest popularity in the district of Nizamabad, especially in the perennially irrigated zone.

Bihar. During 1953-54, more than 500 demonstration plots were laid out all over the State, covering an area of about 5,000 acres, to popularise the Japanese method. The average yield of these demonstration plots was about 3,000 to 4,000 lb. per acre and the highest yield recorded was 9,000 lb. per acre. The increased yield was about four to five times more than the yield usually obtained by cultivators. Encouraged by the previous year's results, the area under the Japanese method was increased to 0.142 and 0.218 million acres during 1956-57 and 1957-58, respectively. Average additional yield obtained by the adoption of this method was reported to be about 1,644 lb. of paddy per acre.

Bombay. This State was the first in India to try the Japanese method of rice cultivation. A special scheme for popularizing this method was sanctioned by the State Government, and 3,498 demonstration plots on cultivators' fields, distributed over the 18 rice-growing districts with assured water supply were laid out. Experiments at research stations and on cultivators' fields were also conducted to test the merits of the method.

From the various experiments and trial-cum-demonstration plots, it was seen that rice responded well to manuring when the water supply was adequate and care was taken in cultivation. It was found that there was considerable scope for reduction of the seed-rate. Interculturing in a transplanted crop gave increased yield. During the year 1956-57, an area of 0.148 million acres was put under Japanese method in the State and an average additional yield of 1,173 lb. of paddy per acre was obtained.

Kerala. During 1954-55, an area of about 30,000 acres was brought under the Japanese method. Want of assured water supply and seasonal vagaries are factors that stand in the way of wider adoption of the method in this State. Efforts are being made to bring the entire area under rice cultivation in the State under this method by the end of the Second Five Year Plan. It is reported that an area of 0.542 million acres was put under this method during 1957-58.

Madras. Modified in minor details to suit the conditions of the State, the Japanese method has been popularized. The beneficial effect of line planting, interculturing and intensive manuring is widely recognized. Area under this method is rapidly increasing and was estimated to be 0.691 and 0.885 million acres during 1956-57 and 1957-58, respectively. Average increase in yield due to the adoption of the Japanese method was reported to be about 572 lb. of paddy per acre.

Orissa. During the year 1956-57, an area of 22,362 acres was put under the Japanese method of cultivation. On an average, an additional yield of 1,615 lb. of paddy per acre was obtained.

Punjab. The Japanese method was popularised in the State with some minor modifications to suit local conditions. The acreage under this method was 0.153 and 0.174 million acres during 1956-57 and 1957-58, respectively. On an average, an additional yield of 661 lb. of paddy per acre was obtained by adopting this method of rice cultivation.

Uttar Pradesh. Extensive trials were conducted in 29 districts which have water facilities, and demonstration centres were opened in the rest of the districts. Experiments on cultivators' fields were conducted to test the merits of the Japanese method. It is reported that during 1957-58 the total area in State under this method was 0.314 million acres. On an average, an additional yield of 623 lb. of paddy per acre was obtained by adoption of this method.

West Bengal. To popularize the Japanese method, demonstration plots were organized in cultivators' fields throughout the State. An area of 55,000 acres was reported to be under this method during 1956-57. It is estimated that, on an average, an additional yield of 1,390 lb. of paddy per acre was obtained by adoption of this method.

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PART II

MARKETING

INTRODUCTION

About half of the world arable land is under cereals, and about fifth of the total cereal area is under rice, 90 per cent. of which is in Asian countries, the chief amongst these being India and China. Pakistan Indonesia, Thailand and Burma come next in importance.

The figures for recent years of world (excluding the U.S.S.R.) output of primary products show that paddy is the most valuable of them all, surpassing not only other crops such as wheat, maize, cotton and sugar, but also coal, crude oil, petroleum and pig-iron, (U.N. Commodity Trade and Economic Devt. 1953). What is true of rice in world context applies to India also.

Considering the fact that one third of the total production of rice is put on the market, it plays an important role in the economy of the country meeting, as it does, cash requirements of numerous small farmers. Few have failed to appreciate the recommendations for increasing production efficiency to achieve national self-sufficiency.

The value of measures to improve efficiency in marketing of rice and other agricultural commodities has not been well understood. The recent survey on marketing of rice in India published by the Directorate of Marketing and Inspection in 1955 shows that relatively small proportion of the price paid by the consumer actually goes to the primary producer, and this has been a continuing grievance. Some of the reasons for this are the prevailing weaknesses in assembling and distribution, inefficiency in processing, excessive reductions both in cash and kind in the market by the intermediaries and other service agencies, non-existence of recognized standards of quality, lack of uniformity in weights and measures, absence of the producers' organizations and weak bargaining strength of the producers.

The primary producer does not feel the hardship, arising as a result of his inadequate share in the consumer's rupee, as long as prices remain at high levels and he has not to pay comparatively more for the goods and services needed by him. It is only when pices fall below remunerative levels that the producer thinks in terms of economy in cultivation costs, increased production and efficient marketing service to get the maximum returns for his produce.

The chapters that follow deal with the various aspects of the marketing of rice in India such as assembling of small saleable quantities from predominantly subsistence farmers, processing, wholesaling, irrational handling charges and malpractices which often add to the cost of marketing.

CHAPTER 22

SUPPLY

World Statistics

ACREAGE: The world acreage of harvested rice, excluding the U.S.S.R., during 1955-56 was reported to be 263.5 million acres as against 262.2 million acres in 1954-55. Of the above acreage 91.8 per cent. was concentrated in Asian countries, and the rest in Western countries, important amongst these being the U.S.A., Italy and Spain. Amongst Asian countries, India and China, the world's largest rice-producing areas, accounted for 29.2 and 27.4 per cent. respectively. The other important areas were Pakistan, Indonesia, Thailand and Burma. These amongst themselves accounted for 20.3 per cent. of the world acreage in 1955-56.

PRODUCTION: Production of paddy in 1955-56 was reported to be 122.6 million tons of which Asia, besides China, produced 109 million tons. Production in China during the same year was estimated at 76.8 million tons, 38.5 per cent. of the world's production and the highest in any country. India which had the highest world acreage, accounted for 19.8 per cent. of the world production. The other important rice-producing areas like Pakistan, Indonesia, Thailand and Burma jointly accounted for 23.3 per cent. of the world output.

INTERNATIONAL TRADE: World trade in rice in 1956 reached a post-war record of 5.5 million tons. Shipments from Burma at 1.8 million tons were less than what had been forecast though the highest since the war, while those from Thailand at 1.2 million tons were the largest since 1953. Exports from the U.S.A. also reached a new high level of 8,05,600 tons. Shipments from China, reported by importing countries, exceeded 3,86,000 tons. These increases in world trade were the largest despite the low-level of shipments from countries of the Indo-China and suspension of exports from India and Pakistan. Japan, Indonesia, Pakistan, Ceylon, Malaya, India and Hongkong were the chief importing countries, their imports being over three million tons, out of 5.5 million tons that entered in export trade.

INDIAN ACREAGE: The average area under rice in India during the quinquennium ending 1955-56 was 75.5 million acres. During this period, the highest acreage was recorded in 1953-54 when it reached a peak of 77.3 million acres. The year 1956-57 saw a further increase in acreage reaching a new height of 78.1 million acres. The trend of acreage for the quinquennium ending 1955-56 is given in Table 75.

TABLE 75.

Year	Area in million acres
1951-52	73.7
1952-53	74.05
1953-54	77.3
1954-55	75.9
1955-56	76.9

Within the Indian Union, Bihar stands out predominantly in acreage followed by West Bengal, Orissa, Madhya Pradesh, Uttar Pradesh, Andhra Pradesh and Madras, as seen from Table 76.

TABLE 76. ACREAGE UNDER RICE IN DIFFERENT STATES IN INDIA

State	Acreage—five years' average ending 1955-56 (thousand acres)	Percentage
Andhra Pradesh	6,043	8.0
Assam	4,214	5.6
Bihar	12,255	16.2
Bombay	3,943	5.2
Kerala	1,812	2.4
Madhya Pradesh	9,399	12.4
Madras	4,908	6.5
Mysore	2,041	2.7
Orissa	9,497	12.6
Punjab	632	0.8
Rajasthan	158	0.2
Uttar Pradesh	8,983	11.9
West Bengal	10,525	13.9
Jammu & Kashmir	457	0.6
Delhi	1	..
Himachal Pradesh	110	0.2
Manipur	199	0.3
Tripura	398	0.5
Andaman & Nicobar Islands	7	
Laccadives, Minicoy & Anumdive Islands	..	..
Total	75,582	100.0

PRODUCTION: The total output of rice, as of any other crop, depends on the area harvested and average yield per acre. These two may be connected. An expansion of area to less suitable land or land where the rainfall and other climatic conditions are less favourable, will tend to reduce average yields. This may have happened in this country where an expansion of area from 62 million acres before

the war to 74 million acres after the war was accompanied by a fall in average yield of padd y per acre from 0.55 to 0.45 tons. Conversely, if the rice area is contracted by transferring low-yielding land to other uses, the average will tend to rise.

The average yield of rice in India for the quinquennium for 1955-56 was about 720.2 pounds per acre, representing an increase of about 13 per cent. over 1951-52. This has been mainly due to increasing emphasis laid on raising food production to achieve national self-sufficiency. The country has been progressively increasing its per acre yield in the First Plan period as brought out in Table 77.

TABLE 77

Year	Yield per acre in pounds
1951-52	637
1952-53	682
1953-54	805
1954-55	724
1955-56	748

The above yields compare favourably with those obtained in Burma or Thailand though they are definitely lower than those obtained in the U.S.A., Italy or China. In 1955-56, among the states in the Indian Union, the highest average yield of 1226·3 pounds was recorded in Mysore. Based on the acreage and the per acre yield, discussed in the foregoing paragraph, the total production of rice during the quinquennium ending 1955-56 is given in Table 78.

TABLE 78

Year	Total production of rice in thousand tons
1951-52	20,964
1952-53	22,537
1953-54	27,769
1954-55	24,531
1955-56	26,846

That India has fairly increased her overall rice production in recent years, is evident from the following index of rice production.

TABLE 79

Year	Yield per acre in pounds
1949-50	100.0
1953-54	118.6
1954-55	105.5
1955-56	122.7
1956-57	118.1

TOTAL AND NET AVAILABLE SUPPLIES

The annual total supplies of rice available for consumption (including seed) for the quinquennium ending 1955-56, after taking into account the local production, imports and exports, are given in Table 80.

TABLE 80

Particulars	1951—52 (in thousand tons)	1952—53 (in thousand tons)	1953—54 (in thousand tons)	1954—55 (in thousand tons)	1955—56 (in thousand tons)
Production	20,964	22,537	27,769	24,531	26,846
Imports	749	722	175	603	205
Total	21,713	23,259	27,944	25,134	27,051
Less exports	..	..	..	23	111
Total available supplies	21,713	23,259	27,944	25,106	26,944
Used as seed	1,300	1,397	1,722	1,521	1,664
Net supplies available for consumption	20,413	21,862	26,222	23,585	25,280

It will be seen that the maximum quantities ever available for consumption in the first Plan period were during the year 1953-54. The imports were also the lowest in that year and, as a matter of fact, were the lowest since the partition of the country in 1947.

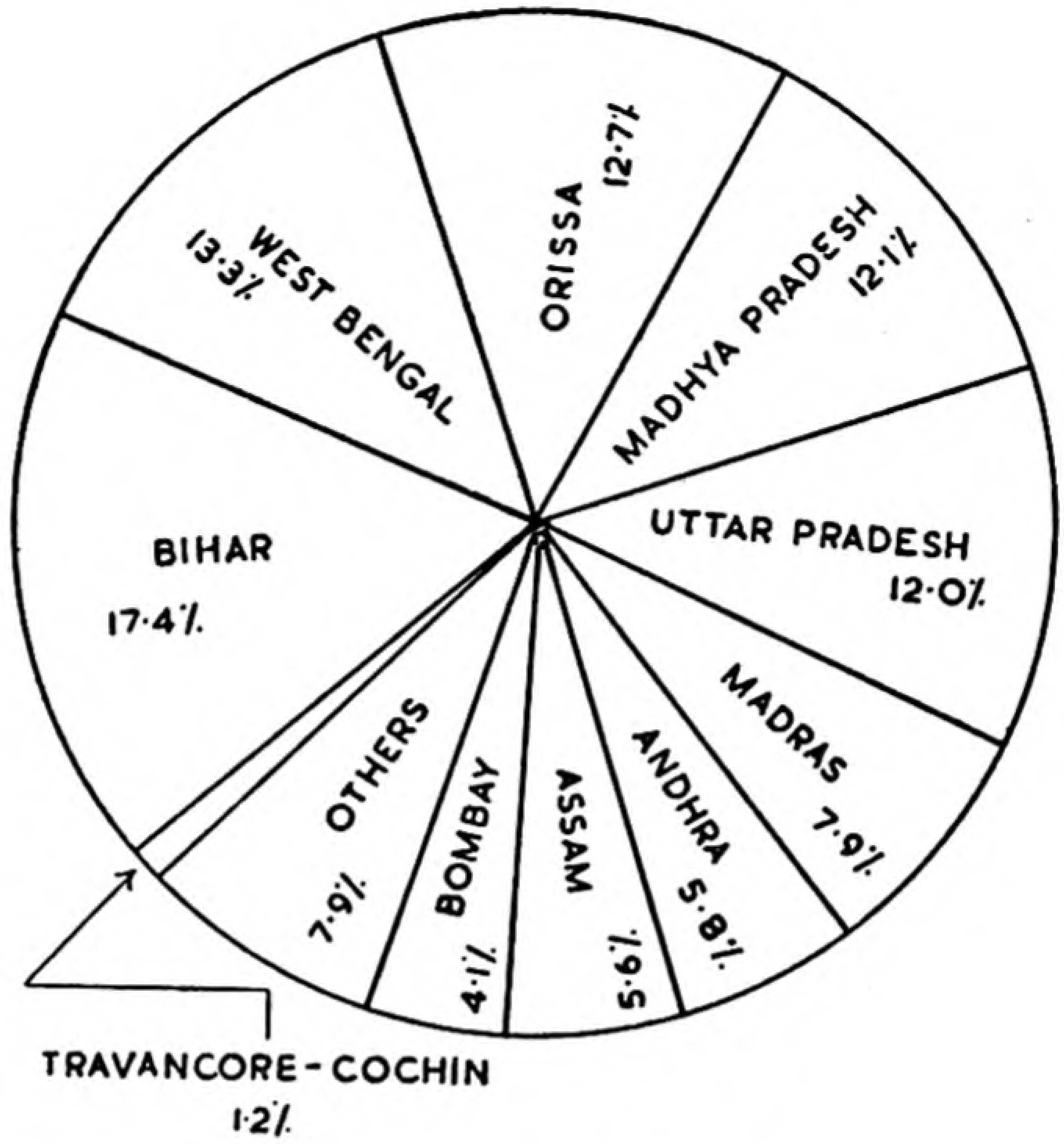
MARKETABLE SURPLUS

India's being a subsistence economy, bulk of the production is retained by the producers to meet their own consumption requirements and also to retain certain quantities for seed, payment of wages, etc. These retentions vary from holding to holding depending on its size and the number of family members maintained on such holding. An *ad hoc* study made in one of the community development blocks of the Punjab, a predominantly wheat-growing area, provided an interesting data as shown in Table 81.

TABLE 81

Range of holding in acres	Marketable surplus per cent. of the total production
0 to 5	48.6
6 to 10	75.9
11 to 15	79.5
16 to 20	78.5
above 20	84.0
weighted average	80.6

AREA



PRODUCTION

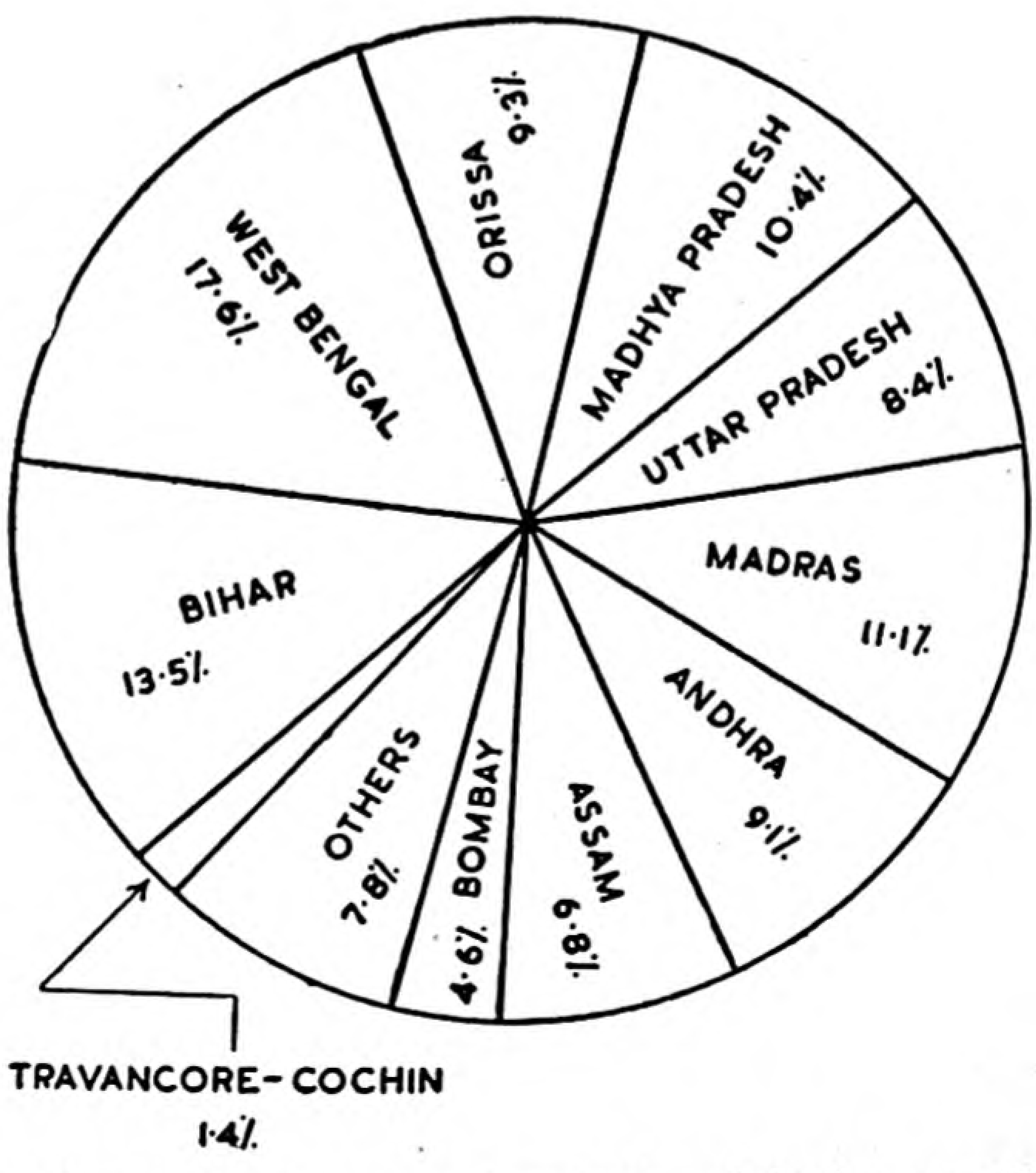


Fig. 42. Share of different states in area and production of rice (average 1950-51 to 54-55)

The Directorate of Marketing and Inspection during the last two years has been compiling statistics of marketable surplus of rice in the country based on arrivals in a number of important rice markets. These figures reveal that about 31·4 per cent. of the total Indian production is put on the market. This surplus, however, varies from state to state, as seen from Table 82 compiled for the year 1955-56.

TABLE 82.

State	Marketable surplus as percentage of production
Andhra Pradesh	50
Bihar	23
Bombay	30
Madhya Pradesh	30
Madras	25
Mysore	53
Orissa	29
Punjab	60
Uttar Pradesh	20
West Bengal	32
Average	31.4

The above ten states account for a production of 23.8 million tons or 88.5 per cent. of India's total production of 26.8 million tons of rice in 1955-56. The total marketable surplus of these states comes to 7.5 million tons or 31.4 per cent. of their production. It would be conservative but safe to presume that the proportion of marketable surplus to production in the rest of the country, accounting for only 11.5 per cent. of the total production, would not be materially different from that for these ten states. Thus, the marketable surplus (from home production) for the country as a whole, for all practical purposes, be put at 31.4 per cent. of the rice produced. It thus works out to 8.4 million tons out of a quantity of 26.8 million tons of rice estimated to have been produced in 1955-56. The position in 1956-57 remained much the same.

MARKETING SEASON

Seasons of marketing vary with the time of harvest in different areas. The disposal of the rice crop commences shortly after threshing, since the producer requires money for the purpose of discharging his various financial obligations. Table 83 summarises the time of sowing and harvesting in the more important states of India.

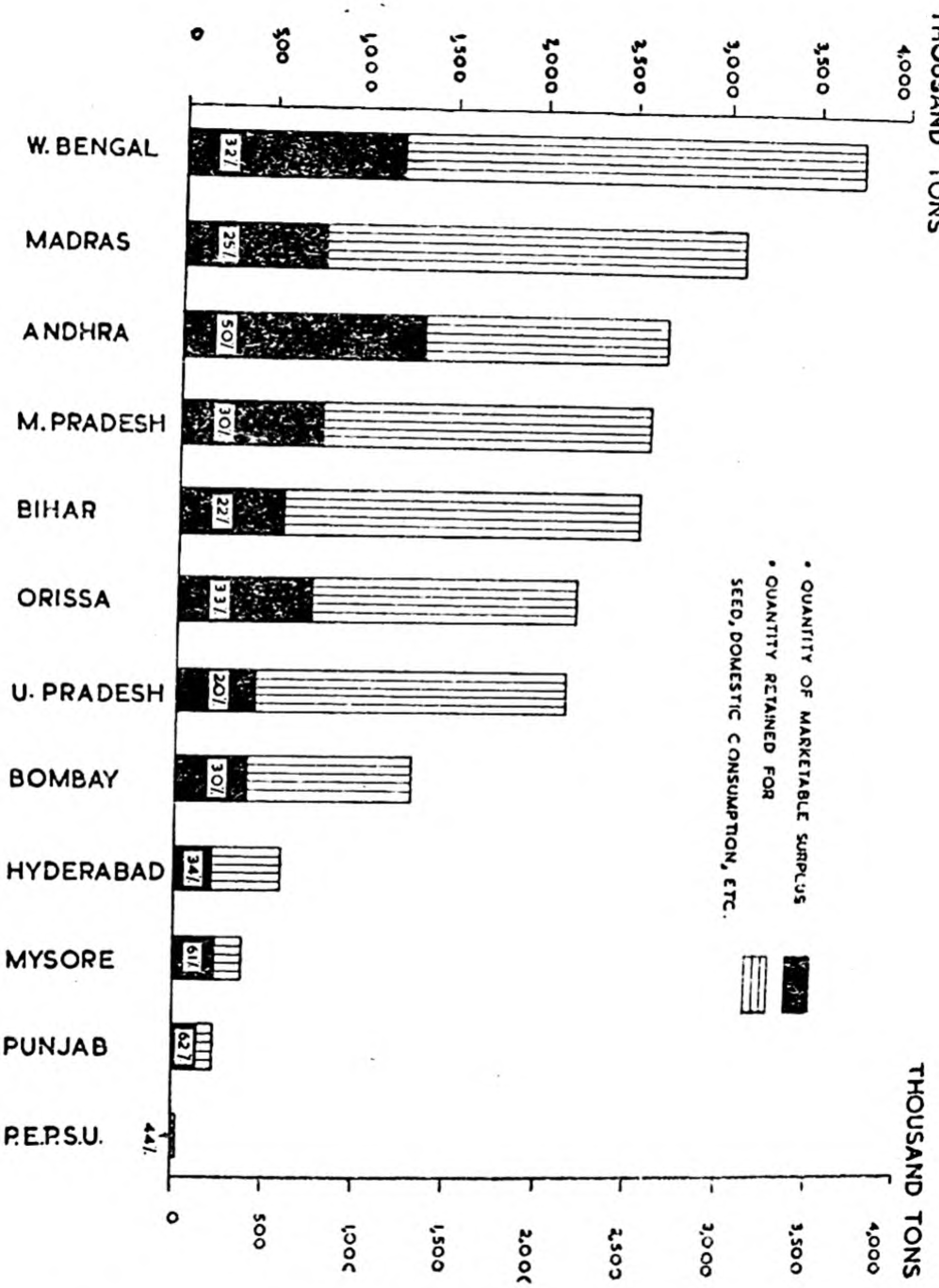


Fig. 43. Percentage of marketable surplus of rice to total production in different States of India

of well over 3. Many fine varieties have ratio over 3·5 and some have as much as 3·75.

The length-to-breadth ratio of the average medium rices ranges from about 2 to approximately 3, with the greater number exceeding 2.5. The only notable exceptions in this case are the *red* and *white Sirumani* varieties of Madras, which have small, round grains with a length-to-breadth ratio averaging below 2. Bold and coarse rices have a large range of length-to-breadth ratios similar to the medium rices, but the tendency is for the ratios to be below 2.5. Table 85, based on the classification referred to above, summarises the position in the main producing areas for the pre-war days.

TABLE 85. CLASSIFICATION OF RICE PRODUCTION IN INDIA ACCORDING TO CONFORMATION (PERCENTAGE OF TOTAL PRODUCTION)

State	Fine	Medium	Bold (or Coarse)
Madras	18	29	53
Uttar Pradesh	14	29	57
Madhya Pradesh ..	13	38	49
Bombay	28	24	48

After the post-war period, and also until recently, there has been a growing tendency for increased production of coarse or bold rice. Numerous factors have favoured this tendency. In the face of acute food shortage, especially during and after the post-war period, the outweighing consideration has been that of quantity and not of quality. Secondly, the yield from bold varieties is higher than from that of fine or medium varieties. Further, the hulling outturn from bold varieties is also higher. Thirdly, the minimum prices fixed during the procurement periods in most cases did not correspond to the numerable quality differences. It is rather difficult to estimate the exact extent to which this tendency has actually developed. All that is possible, is to illustrate its growth by certain examples, *e.g.*, it has been estimated that both in Madras and Orissa, the bold varieties now constitute 60 per cent. as against 53 per cent. during the pre-war period. Similarly, it is estimated that in the partitioned Punjab, the proportion of bold qualities is now 73 per cent. as against 63 per cent. in the pre-partition Punjab. In view of these estimates, it may be roughly stated that the proportion of bold varieties in India might be about 60 per cent. as against 55 per cent. in the pre-war period.

TREATMENT GIVEN PRIOR TO HULLING

Depending on the treatment given to paddy prior to hulling, rice may be divided into two classes, *viz.*, raw and parboiled. The former is not subjected to any form of treatment prior to hulling, while in the case of parboiled rice, the usual practice is to first steep the paddy and subsequently apply heat by steam or other means. This toughens the rice kernel and enables it to withstand milling better

without excessive breakage. The greater proportion of the rice grown and used for consumption in India is parboiled. Usually, the bold and coarse varieties are chosen for parboiling. The practice of parboiling is more in vogue in West Bengal, Bihar, Orissa and Kerala. In the post-war period, parboiling has been on the increase. It has been estimated that in Madras, 40 per cent. of production comes under this category, as against 32 per cent. in the pre-war days. In Kerala, the corresponding figure is said to have increased from 92 to 95 per cent. Slight increases are also estimated in Bombay and Madhya Pradesh. However, these are not only a few, but are also rough estimates. The forces which have been working in favour of increased use of parboiling are similar to those responsible for the higher production of coarse varieties. The outturn of whole rice from parboiled paddy is larger in proportion to brokens or fragments.

METHOD EMPLOYED FOR CONVERTING PADDY INTO RICE

The method used for converting paddy into rice places rice into two classes, *viz*, 'machine-milled' and 'hand-pounded'. Machine-milled rices are prepared by power-driven hullers while in the case of hand-pounded rices, the husk is removed by the pestle and mortar method. The latter practice is still very extensively in vogue. Table 86 below shows the percentage of the hand-pounded and milled rice to the total production in the important states.

TABLE 86

State	Hand-pounded	Machine-milled
Assam	66.0	34.0
Bombay	36.5	63.5
Kerala	69.5	30.5
Orissa	87.2	12.8
Madhya Pradesh ..	79.1	19.9
Bihar	97.4	2.6
West Bengal	70.2	29.8
Andhra	50.1	49.9
Mysore	4,3	95.7

The proportion of the production of the types and qualities discussed above which is put on the market is not the same in the case of different classes of rice, as would be seen from Table 87 which though relating to the pre-war period, would be found useful.

TABLE 87. PERCENTAGE OF PRODUCTION OF DIFFERENT VARIETIES CONSTITUTING MARKETABLE SURPLUS

State	Fine	Medium	Bold	Machine-milled		Hand-pounded	
				Raw	Parboiled	Raw	Parboiled
Bengal	95	80	16	*	*	76	34
Madras	97	85	48	91	92	37	20
Bihar & Orissa	90	50	9	*	94	38	24
Uttar Pradesh	90	60	14	*	*	34	30
Madhya Pradesh	90	50	16	95	*	13	—
Assam	83	8	3	*	*	3	2
Bombay	80	40	9	50	*	17	—
Punjab	89	81	45	66	*	—	—
Hyderabad	86	70	47	84	—	12	—
Mysore	*	80	26	77	*	27	—
Baroda	*	88	71	*	—	60	50
Other states	79	60	38	*	*	26	36
Grand Total ..	87.9	63	28.5	75.6	94	27	26

* Practically all
— Nil

It will be observed from Table 87 that the proportion of the production which is put on the market is much higher in the case of fine rices as compared with bold (coarse) rices. Again, a comparatively large proportion of the production of parboiled rice is put on the market. The bulk of the machine-milled rice enters commerce, whereas hand-pounded rices are principally consumed by the growers themselves.

Besides the size and shape of the grain and the variations due to the treatment given prior to hulling, and the methods employed for hulling, there are a number of other characteristics which constitute quality factors for rice. These are the translucency, colour, polish, fragrance, age and cooking quality. The amount of foreign matter and impurities present, and the proportion of broken grains, damaged grains, weevilled grains, red grains and admixture with grains of other varieties also have a bearing on quality. Translucency indicates a hard kernel structure, which implies freedom from any tendency to coagulate on cooking; translucent rices are reckoned as of higher quality in respect of colour, and, as a rule, the whiter the

colour, the better the quality, and hence higher the price. There are, however, exceptions to this rule. Polish, which is highly esteemed in western countries, is not a universally appreciated characteristic in India; hand-pounded rices are generally devoid of polish. On the other hand, natural fragrance or aroma is a much-valued quality factor, particularly where the scent persists after the rice has been cooked. Age or maturity is a factor closely allied to cooking quality, and has a special significance in all the higher-priced fine rices. Cooking quality largely depends on the age and structure of the grain. Matured rice is superior to new rice in this respect. Fine rices generally show elongation and separation of cooked grains, while the cheaper, medium and coarse rices are well all over and show a tendency to become mushy. Foreign matter and impurities in rice do not generally exceed a half per cent. The percentage of brokens, on the other hand, may range from less than one per cent., in the case of specially sifted rices, to over 63 per cent. in the case of raw, soft, chalky varieties. Damaged grains are usually less than one per cent. The proportion of weevilled grains varies considerably. Many commercial samples may show no weevilled grains, while others may have as much as seven per cent. The proportion of grains having a red cuticle may vary from nil to 12 per cent., but is generally fairly low, particularly in machine-milled rices.

CHAPTER 23

UTILIZATION AND DEMAND

Paddy, besides being converted into rice, is utilized as seed for sowing, for stock-feeding and for the manufacture of parched products. The total quantity of paddy required to sow 75.55 million acres (average for five years ending 1955-56) is estimated at 2.3 million tons of paddy, equivalent to 1.43 million tons of rice, representing 6.2 per cent. of average total production. Its utilization as a stock-feeding in this country is negligible. Paddy is, however, utilized for the manufacture of parched products almost all over the country and in particular is utilized in substantial quantities in West Bengal, Uttar Pradesh, Bihar and Orissa. These four States account for three-fourths of the total demand of paddy for parched products in the country. The rest of the production is converted into rice either by machine-milling or hand-hulling or hand-pounding. Machine-milling of paddy is comparatively more important in the States of Mysore, Bombay, the Punjab and Madras. Table 88 shows the quantities milled and hand-pounded in some of the important states.

TABLE 88. TOTAL ANNUAL RICE OUTPUT IN TONS

State	By rice mills and small hullers	Hand-pounded
Assam	200,000 to 500,000	900,000
Kerala	75,000	200,000
Orissa	270,000	2,500,000 to 3,000 000
Madhya Pradesh ..	500,000	1,800,000
Bihar	100,000	3,500 000
West Bengal	1,400,000	3,300 000
Andhra	9 58,269	38,892

The export demand for paddy is practically negligible. There has never been any demand from outside for Indian paddy.

Utilization of Rice. Rice is utilized for various cooked preparations, for industrial and non-edible uses or for the preparation of parched products.

Rice is the most important single article of food in India. In many parts of the country, 90 per cent. of the production is consumed in various cooked preparations, the great bulk as plain boiled rice. The other rice preparations are *kheer* and *firni*, made by boiling rice in milk with addition of sugar to taste. *Pulao* is yet another rich preparation of rice cooked in *ghee* (clarified butter) usually with mutton or lamb with or without vegetables and spices and dry fruits. In addition to the above-mentioned preparations, there are a number of other preparations peculiar to south India, *e.g., puttu, dosai, iddli, uppma* and *appam*.

The industrial uses to which rice is put in India comprises the use of rice as starch by laundrymen and for sizing purposes in the cottage weaving industry and small quantities of rice flour used in the indigenous cosmetic industry. Regarding the manufacture of products, conflicting tendencies have been at work during the post-war period in regard to conversion of rice into manufactured products such as parched rice (*murmura*) or beaten rice (*chura*). Controls and rationing led to restrictions on the use of rice for these purposes.

The manufactured products have, however, been separately dealt with elsewhere in this Section.

Per capita consumption of rice. The per capita consumption of rice in the different regions of India displays wide variety, depending upon the food habits and consumer preferences of each tract. The figures in Table 89 show that the consumption of rice per capita varies from an insignificant quantity of 20 lb. per annum in the Punjab to 314 lb. in West Bengal. The most important rice-eating states in descending order are West Bengal, Assam, Madras, Madhya Pradesh and Bihar. In other areas, consumption is comparatively lower.

TABLE 89. PER CAPITA CONSUMPTION (IN LB.)

West Bengal	314
Assam	305
Madras	256
Madhya Pradesh	222
Bihar	211
Andhra	184
Kerala	157
Uttar Pradesh	74
Punjab	20

Consumption of rice also varies in different parts of the same state. For instance, it is much lower in Calcutta than in other parts of West Bengal. Similarly in Madras and Bombay, rice constitutes a more important part of the diet in the coastal areas. In Madhya Pradesh, the consumption of rice is much higher in the eastern districts where the bulk of rice is consumed than in Berar and other southern zones where wheat is more popular. Same is the case in Uttar Pradesh where the consumption of rice is much heavier in the eastern and sub-montane parts than in the western parts.

QUALITY REQUIREMENTS

Paddy. Medium, sound grains of paddy are considered most suitable for use as seeds for sowing. Pure seeds distributed by the Agricultural Departments usually fetch a premium for this purpose. For preparation of parched products, medium varieties are commonly used, though fine and bold varieties are also used

in certain areas. For instance, in West Bengal, the fine varieties *Hamai* and *Patnai* are made into parched and beaten rice respectively, while a medium variety is used for the manufacture of parched rice. The demand for paddy for stock-feeding as already mentioned is quite negligible, and only the bold and inferior varieties are used for this purpose.

Rice. Fine rices which are comparatively costly are generally in demand by well-to-do classes, while the less expensive medium and bold varieties are patronized by persons of moderate means and by the labouring classes, respectively. The consumers in certain areas differentiate between the milled and hand-pounded rices, and between artificially-coloured rices and those which are marketed in their natural state. More than three-fifth of the consumption of fine rices consists of the raw variety. The demand for parboiled fine rices which are as a rule less costly, is in the large rice-growing states of West Bengal, Bihar and Orissa. Ordinary raw fine rices less than six months old and fine-scented varieties of northern India which are less than a year old, are not much in demand. In some cases, consumers look for rice which has been stored for a length of time.

Medium rices are consumed mainly in the form of plain boiled rice and sweet rice. The same importance is not attached to age as in the case of the fine rices, although there is a preference for rices not less than six months old. The demand for parboiled medium rices is a particular feature of the trade in West Bengal, Bihar, Orissa and Kerala. The bold rices are used for plain boiling and, to some extent, for *khichri* and *kheer*. These are not usually stored long for attaining maturity.

Parboiled rices are used for preparations which necessitate cooking for longer periods. The consumption of parboiled rices has increased considerably in recent years.

A very large proportion of the rice consumed in India is hand-pounded rice. Consumption of machine-milled rice has increased in recent years. This is particularly the result of the recent tendency to replace manual work by labour and time-saving devices. Another important factor, however, is that milled rices are generally cheaper than hand-pounded rices. Research has established the superiority of lightly or hand-milled rices from the nutritional aspect, and hand-pounded rices are thus finding increasing favour. In their recommendations, the Rice Milling Committee have emphasised that in future no licences for new rice mills should be granted, and that recognized hand-pounding centres organized as co-operative societies by recognized institutions and social workers or by the trade engaged in hand-pounding rice and working on factory-scale should be introduced in all states under the Essential Commodities Act, 1955, where this has not already been done under the State Act.

The demand for artificially coloured rices which are prepared by colouring raw rice is confined mainly to the few areas probably in South India and Bombay, although coloured rices are available for sale in a number of markets all over the country.

Broken rice, being ordinarily the cheapest kind obtainable, is almost entirely used for edible purposes by the poorer classes, in contrast with industrial countries where broken rice is largely used for the manufacture of starch, for distilling, etc.

Only small quantities of broken rice are utilized for feeding poultry and by laundrymen and the cottage weaving industry. The total quantity of broken rice produced and marketed, however, is estimated at about ten per cent. of the marketable surplus. It is not possible to assess the extent of the demand for broken rices with any accuracy as no records are available. The demand for Indian rices in the foreign markets is mainly for parboiled varieties of the fine and medium classes. In the recent past, there has been a ban on the exports of rice from this country. But when there was no restriction, Ceylon took the small, round grain, *white* and *red Sirumanis* from Madras, while Mauritius, South Africa and the Arabian Ports were buyers mainly of parboiled and *Patnai*, and to a relatively smaller extent of *Sitasal*, both of which are from West Bengal and north Orissa. High grade parboiled *Patnai*, containing uniformly large, long grains without any admixture of other varieties and brokens was in demand in the United States of America and Canada by the manufacturers of canned foods. There used to be a small trade with the United Kingdom and certain other countries in Continental Europe for the hand-husked raw type which is produced from *Patnai* paddy. This was not sold in the form in which it was exported, but was imported by European countries for remilling and marketing as a high grade product.

In the main rice-producing states, *e.g.*, West Bengal, Bihar, Assam and Orissa and in many parts of Madras and also in some of the eastern districts of Madhya Pradesh where rice is the staple food, the consumption of rice varies so little in the course of the year, that for all practical purposes, demand may be regarded as constant. On the other hand, in the districts in which rice production is not large, and where foot-crops constitute the staple food, *e.g.*, the Punjab, the western districts of Uttar Pradesh, Madhya Pradesh and Rajasthan, the consumption of rice is the greatest when the weather turns hot and dry two or three months before the rains break. Little rice is eaten during the monsoon.

In the case of paddy, the demand from the mills is greatest in the period immediately following harvest and is generally at a low level during the monsoon.

CHAPTER 24

WHOLESALE PRICES

Well-organized assembling markets or *mandis* to which paddy is brought by growers for sale are almost absent in India. A considerable part of the marketable surplus of paddy is normally acquired directly from the field by the rice-millers or their agents, by traders of various categories and professional dehuskers. Thus a large portion of the paddy produced never enters the market. Price data in respect of paddy is, therefore, scanty and, when available, is biased in many instances by the conditions in which it changes hands.

Indian rice is unique in that normally there is wide range of prices. Some of the important factors which seriously handicap a scientific treatment of the subject of rice prices are the existence of an extraordinarily large number of consumer-preferences and the localized nature of the demand. The non-existence of standard qualities adds further to the magnitude of the difficulties involved in analysing rice prices. For instance, in large consuming and distributing centres of Bombay and Calcutta, on any day during normal times there will be as many as 150 to 200 quotations for various grades of 40 or 50 varieties ordinarily handled by the local trade. Besides varieties, certain physical characteristics also count among the price-determining factors. For example, prices vary according to conformation. Fine varieties are dearer than medium and medium ones than bold (coarse). The price of rice also depends on whether it is raw or parboiled, the latter usually being cheaper. The process of dehusking or milling also has a bearing on price. The other important quality characteristics which influence prices are whether rices are hard or soft as judged by their translucence or chalky colour, whether polished or unpolished, whether uniform in size and shape, their age (particularly in respect of the high-priced fine varieties) and cooking quality. Broken grains and admixture of other varieties or damaged and defective kernels are also important factors. When studying Indian rice prices, it is essential to bear in mind that there being no standard of quality for comparison, physical characteristics are assessed merely by visual examination, the accuracy of which depends solely upon skill and experience. Thus the concept of quality is capable of so wide a range of interpretation in different parts of the country that the quality factor cannot be translated into precise terms of value.

INDIAN AND WORLD PRICES

In theory, every commodity should have what may be termed 'a world price', a price to which value in each country should be related along with transport cost, quality variations and the time factor. In the case of rice, it is practically impossible to determine what the world prices should be, owing to the fact that in contrast to the other two chief world cereals, wheat and maize, international trade in rice is widely distributed over a very large number of countries with vast differences in costs of production and marketing. After the First World War, comparison

between the prices ruling in different parts of the world tended to become increasingly complex owing to the creation of artificial conditions imposed through their various restrictive measures on the free movement of trade, through tariff walls, quotas, currency regulations, barter agreement and sometimes even by total prohibition. Similarly, World War II greatly dislocated trade and transportation and disrupted the relative level of prices in different countries. International trade in rice during and since World War II has been regulated by special measures of control and allocation on both national and international levels. Until decontrol, the internal rice prices were almost every year, under Government control while the import prices were subjected to negotiation between the exporting and importing countries. In consequence, certain exporting countries had developed unrelated rice price structures, one for the internal trade and other for the export trade.

Since Indian import even in the post-War period are chiefly from Burma, it may be of some interest to note the trend of average prices of rice exported from Burma (Table 90).

TABLE 90. EXPORT VALUE OF BURMA RICE

Year	Rs. per ton
1947	384
1948	522
1949	605
1950	539
1951	583
1952	777
1953	827
1954	731

Calculated from the total quantity and value of rice exported from Burma, based on the year October-September during the same period. Commodity Policy Studies No. 7, F.A.O.

Annual wholesale prices. The All-India index of wholesale prices of rice, percentage of variation, and its average prices are brought out in Table 91.

TABLE 91. ALL-INDIA INDEX NUMBERS OF WHOLESALE PRICES OF RICE (BASE: 1952-53—100)

1953-54	54-55	55-56	56-57	1957						Average for 3 months ending Sept. 1957
				April	May	June	July	August	Sept.	
100	82	78	96	101	106	107	108	111	107	109
Average (+)9.0	(+)32.9	(+)39.7	(+)3.5	(+)7.9	(+)2.8	(+)1.9	(+)0.9	(+)1.9	(+)1.9	

SEASONAL VARIATION IN PRICES

The prices of rice and paddy are subject to well-defined seasonal changes which are more pronounced in the case of paddy. This is so because the primary seller of paddy is invariably the cultivator who has to dispose of all his paddy in the months immediately following the harvest. The primary seller of rice on the other hand, is the merchant, miller or professional dehusker who may possess finances and storage facilities. In the case of both rice and paddy prices, the prices are generally depressed between December and May which is a period of large supplies. As the season advances, a rise in prices usually takes place which after reaching the highest level in the late summer and autumn, begins to recede again as would be seen from the All-India index number of wholesale prices for 1956 and 1957 (Table 92).

TABLE 92. ALL-INDIA INDEX NUMBER OF WHOLESALE PRICES OF RICE FOR 1956 AND 1957

(BASE: 1952-53—100)

1956		1957	
January	77	January	91
February	79	February	96
March	86	March	97
April	92	April	101
May	93	May	106
June	95	June	107
July	97	July	108
August	100	August	111
September	101	September	108
October	100	October .. (week ending 9-10-57)	108
November	99		
December	93		

THE PRICES OF DIFFERENT QUALITIES OF RICE

The prices of different qualities of rice found in a market vary depending on whether the rice is fine, medium or bold (coarse), raw or parboiled, hand-pounded or machine-milled, whether it has a natural tinge or is artificially coloured, and on the age and the proportion of impurities, broken grains etc. Generally, fine rices are relatively costly and bold or coarse varieties cheap. Medium rices are of intermediate value. There are, however, wide divergencies between the relative value of rices in these three categories in different areas as will be seen from Table 93.

TABLE 93. RELATIVE VALUE OF RICE IN SOME STATES

State	Fine		Medium		Coarse	
	Trade description	Price per md.(82.1/7 lb.)(1955)	Trade description	price per md. (82.1/7 lb.) (1955)	Trade description	Price per md.(82.1/7 lb.)(1955)
		Rs. As. P.		Rs. As. P.		Rs. As. P.
West Bengal	*Bhansmanik*	19 3 0	*Nagra*	17 6 0	*Latimole*	16 13 0
Madhya Pradesh	*Kali Kamod*	23 0 0			*Gurmatia*	15 0 0
Madras	*Kichli Samba*	19 0 0	*Sirumani*	16 8 0	*Kattari Samba*	15 8 0
Andhra	*Krishna Katukulu*	21 8 0	*Akulu*	16 0 0	*Kusuma*	19 0 0
Punjab	*Basmati*	36 0 0	*Begmi*	20 0 0	*Joona*	17 8 0
Bihar	*Kalam Katti*	25 0 0	*Dhdhraj*	23 12 0	*Matscfi*	17 0 0

The price relationships given above between three classes of rice in different areas are approximate indications only and do not remain constant as the prices of each class are liable to fluctuate independently of one another.

Parboiled rices are generally cheaper than the raw rices prepared from the same paddy, the difference generally varying from Rs. 1 to Rs. 1-8-0 per maund in respect of fine and medium rices and anything from Rs. 0-8-0 to Rs. 0-12-0 per maund in respect of bold rices. It is primarily due to the fact that the parboiled treatment reduces breakage in husking, and gives a high turnout of whole rices.

Hand-pounded rices are generally dearer than machine-milled in the fine and medium classes with the exception of some medium varieties in Bengal. The difference is partly accountable for by the extra cost of manual labour involved in hand-pounding. In the case of bold rices, however, the hand-pounded quality does not always obtain a premium over machine-milled one.

Rices tinted by external application of colouring agents are in most instances sold at a small premium which seldom exceeds a few annas per maund.

Rice which has to be stored for some time or that produced from stored paddy generally sells dearer than the newly harvested produce. Such difference in price is only in regard to raw and not for the parboiled types which with a few exceptions in West Bengal, are not stored in the normal course of trade with the object of attaining maturity. The price difference between old and new rices occurs early in the season at a time when new crop arrivals are fresh on the market. During this period which may last for a few months, new rice is not regarded really fit for immediate consumption, and in consequence, quotations for such a produce are normally at a discount compared with those of the previous year's crop. All types of rices including those in the bold category, are generally affected in this manner for shorter or longer periods depending on the local supply conditions.

TABLE 94. PRICES OF OLD AND NEW RICES IN THE CALCUTTA MARKET DURING FEBRUARY, 1956

State	Trade name of rice		Price per maund	
			Old	New
West Bengal	*Bhansmanik*	Fine	Rs. 20 0 0	Rs. 18 4 0
	Nagra	Medium	Rs. 17 8 0	Rs. 16 0 0
	Sadamota	Bold	Rs. 16 12 0	Rs. 15 12 0

VARIATIONS IN GRADE OR QUALITY

Regarding the difference in price due to variations in the amount of impurities, broken grains etc., with the exception of certain specified varieties of rice for which grade specifications have been laid down comparatively recently under the provisions of the Agricultural Produce (Grading and Marking) Act, 1937, no generally accepted standards of quality are recognised in respect of Indian rice. A comparatively small number of establishments, mills and traders have their own private trade marks or brands, which may be distinguished by fanciful names or series of numbers such as 1, 1½, 1¼, etc., but the qualities represented by these samples are nowhere regulated, and may, in fact, change from season to season according to the selling policy of the firms concerned. It is also not the custom in India to analyse samples of rice (or paddy) by separating out and determining the various components such as broken grains, fragments, damaged grains, etc., in the same way as is done for wheat and other foodgrains as well as oilseeds. Standard contracts such as exist for most of these commodities in important markets and notably at the terminals, i.e., at Bombay and Calcutta, are conspicuous by their absence in the rice trade. The basis for judging quality depends on trade usages and the variety of rice. For instance, broken grains and fragments are generally regarded as of first importance in assessing the value of raw rice, while the proportion of red grains is often the chief criterion for evaluation of parboiled types. Colour and polish may be stressed in one area, but regarded as of only secondary importance in another. Similarly fragrance or aroma is not everywhere appreciated.

The presence of weevilled grains lowers the value of rice in some tracts, but in others, provided the number of weevilled kernel is not unduly large, enhances the price on account of its being an indication of age and maturity, a much-desired quality of fine rice.

Some of the variations in price due to quality or grade can be had from the few examples during the period of controls in some areas of India. In 1947, the difference between price of *Kolam* C and *Kolam* A at Surat (Bombay) was as high as Rs. 1-14-0 per maund, or 12½ per cent. *Kolam* B was sold at Rs. 15-10-0 per maund,

that is ten annas, or over four per cent. above that of *Kolam* C. At Nasik in the same year, the difference in price between No. I and No. II was Rs. 1-5-4 or nine per cent. only. In Madhya Pradesh, the difference in price at Nagpur and Jabalpur between Medium I and Medium II in the year 1947 was Rs. 2-3-9 per maund, and amounted to 18 per cent. In West Bengal at Budge in the same year, the difference in price between Grade B and Grade C was as high as Rs. 5 per maund, and worked out to over 44 per cent., as Grade B was sold for Rs. 16-4-0 per maund while Grade C was priced at Rs. 11-4-0 per maund. The variations in this vast country are so wide and the influence on prices of diverse characteristics and quality factors so complicated and unpredictable that the data collected may only be taken as a rough indication of the position in this regard.

PRICES OF DIFFERENT QUALITIES OF PADDY

The prices of different qualities of paddy are determined by conformation or grain-size, milling quality, and physical characteristics such as impurity contents, proportion of damaged or defective grains, red grains, admixture of other varieties and moisture content. Paddies from which fine rices are derived are normally dearer, while those from which bold rices are produced are the cheapest. Paddies producing medium rices fall between these two extremes. The difference between fine, medium and bold paddies are somewhat smaller than those in the case of rices.

The milling quality is generally judged by the rough and ready test of rubbing a few grains of paddy between the palms, or between two small wooden boards to remove the husk and disclose the rice kernel. The sample which husks readily without an unduly large breakage of kernels is considered to be of good milling quality, while the one having a thick husk or is hard to husk or showing a tendency for the kernels to disintegrate, is considered of poor milling quality. Paddies regarded as being of poor quality sell at a discount which varies with the fine, medium and bold types. Differences are more pronounced in tracts noted for raw rice production.

A premium varying from five to 20 per cent. of the new crop values, is paid for paddies harvested 12 to 15 months previously in respect of a number of fine and medium varieties of paddy in several rice-growing areas.

The value of paddy also takes into account the presence of foreign matter, undeveloped grains, admixture of other varieties and moisture content, but as there is no fixed basis and values are assessed by visual examination alone, it is not possible to relate these factors to price differences. In many areas, it is customary for allowances to be conceded by the seller to the buyer in the shape of extra weight to compensate the latter for the presence of foreign matter, impurities etc., as well as moisture in the grain.

RELATION BETWEEN THE PRICE OF PADDY, RICES AND DERIVATIVES

For all practical purposes, three units of paddy are reckoned to yield, on an average, two units of rice, ignoring a small proportion of fragments or particles of rice. Actually, however, the outturn of rice from a given quantity of paddy will vary according to the variety, the method of processing adopted and the degree of milling given.

As the yield of rice from paddy is reckoned at about 66 per cent., the price of paddy should theoretically be in the neighbourhood of 66 or 67 per cent. of the value of rice. Actually, this is often far from the case, and the relative values of paddy and rice show wide divergencies brought about by a number of factors. In the first place, the values both of paddy and rice are liable to fluctuate independently on account of the many quality factors and market conditions. Secondly, the price-relationship between paddy and rice will depend on the methods adopted to convert the paddy into rice. The cost of hand-pounding, for example, is different from that of machine-milling, while parboiling adds to the processing cost. Thirdly, it costs more to turn out highly milled rice than to produce rice which is lightly milled. And finally, the proportion of broken grains and fragments of rice allowed to remain in the rice determines the price at which the finished article can be sold.

RELATION BETWEEN PRICES OF PADDY AND RICE OF DIFFERENT VARIETIES

In Madras, for instance, the relationship which normally prevails between paddy and rice of different varieties does not differ very greatly as would be seen from Table 95.

TABLE 95. PRICES OF DIFFERENT VARIETIES OF PADDY AND RICE IN MADRAS

District	Variety	Price during week ending 11.5.1955	
		Paddy 1st. sort	Rice 1st. sort
Vellore	*Chanisanka*	Rs. 8 8 0	Rs. 12 12 0
Kumbakonam	*White seromani*	Rs. 9 0 0	Rs. 14 4 0
Tirunelveli	*Annakomban*	Rs. 8 13 0	Rs. 13 8 0

What is true of Madras is also true of West Bengal. There is, however, a greater disparity between paddy and rice values in respect of the fine rices of northern India, which are more susceptible to breakage and often involve a good deal of dressing and sifting. Thus, the proportion which the price of paddy bears to rice in northern Indian fine rices may be anywhere between the extreme limits of 35 and 75 per cent.

MARKET INTELLIGENCE

Despite the fact that the marketing intelligence is presently being disseminated through the medium of Government publications, the daily and trade press, post, telegraph, telephone and radio yet, by the very nature of the produce, such marketing intelligence is not more than of local importance.

Three elements are probably accountable, more than anything else, for some of the unique conditions of market intelligence concerning rice as compared with other important cereals and oil seeds of commerce, such as wheat, linseed, groundnut, etc. These are due to the lack of any recognized standards of qualities, the localized character of demand and the absence of trading in 'futures.' Another factor which contributes to the confusion is that the system of buying Indian rices on standard contracts is nowhere in vogue, and the multiplicity of commercial description adds many complications to any comparison of prices and makes it practically

impossible to relate prices in one market with those in others. Defective communications and poor market facilities in major rice tracts like Bihar, West Bengal, Assam and Orissa, are yet other contributing factors preventing proper dissemination of marketing intelligence.

The trade, however, tries to keep itself in close touch with the prices. The cultivator is usually unaware of the day-to-day prices. Unless he has himself been to the market, he normally gets his news by words of mouth from such of his neighbours as may have recently visited the local assembling centres or from the village merchants and peripatetic traders. If the growers are to get better prices for the fruits of their labour, the speedy dissemination of reliable market information in an intelligible form is a fundamental necessity.

CHAPTER 25

PREPARATION FOR THE MARKET

The rice crop is reaped entirely by manual labour, the ordinary sickle being used for the purpose. The harvesting is usually done when the rice kernels in the lower part of the head have not hardened complctly or the upper parts of the leaf-blades have not turned completely dry. In some regions, the crop is threshed as soon as it is cut while in others, a certain amount of time, varying from a week to two months, is allowed to elapse after reaping during which period the grain dries out properly and the rice kernel hardens within its covering of husk. The producer is, however, usually anxious to dry the sheaves as rapidly as possible, and does not fully appreciate that the technique of handling the crop during this intervening period has a bearing on the hulling quality of his paddy. Threshing is done either by beating the sheaves against a block of wood until the paddy grains are separated from the straw, or by bullocks treading the sheaves laid on the threshing floor. The beating process, apart from being probably more economical, gives a cleaner paddy as by the bullocks treading the sheaves, the straw is broken into pieces making it of little use for making thatch. When threshing is done by beating the sheaves, a little dressing may be required to remove whatever chaff as may have found its way into the produce. If paddy has been trodden by bullocks, the grain is usually separated from the chaff and impurities by winnowing.

The operations connected with harvesting are all done by the cultivator and his family, or by employing hired labour. The wages may be paid in cash or in kind. Special enquiries made in 1948 revealed that in Madras, one to 1½ *kunsums* of paddy are given as daily wage for harvesting, 15 *kunsums* of paddy are given as payment for cutting and reaping, and ten *kunsums* per acre as threshing charges (24 *kunsums* make one bag of two standard maunds). The harvesting charges for one acre thus come to slightly over one bag of paddy, i.e., 112 pounds, the price of which at the time of the enquiry was between Rs. 7 and Rs. 9. which appears to be an exceptionally low cost, though higher than pre-war cost anywhere. The harvesting costs vary from area to area in the same state. Thus it was found that in Madras, the harvesting cost ranged from Rs. 0-8-2 per maund, in Malabar and South Kanara districts, to Rs. 1-8-0 per maund in the districts of East Godavari, West Godavari, Krishna and Guntur. Similarly, in West Bengal, the harvesting cost varied from Rs. 1-4-0 per maund in the Burdwan district to Rs. 2-12-0 per maund in the Hooghly district. The average for the whole State was estimated at rupees two per maund. The variation was mainly due to varying labour charges during the harvesting season in different areas. Threshing and winnowing charges were estimated to account for a little less than one-third of the total cost in West Bengal. In Madhya Pradesh, the harvesting costs have been estimated at Re. 0-12-6 per maund of paddy, or Rs. 9-11-0 per acre, as against Rs. 5 per acre in the pre-war period.

PARBOILING

Parboiling is the process of steeping paddy (before it is husked) in water and subsequently applying heat by steam or other direct means making the husk more easily removable and toughening the rice-kernel, enabling it to withstand hulling and milling better. Before describing some of the methods used in the parboiling of paddy, it is necessary to distinguish between commercial parboiling and domestic parboiling. Commercial parboiling is important in relation to machine-milled rice as the bulk of the total output of parboiled milled rice is put on the market. On the other hand, the domestic parboiling is the larger factor, as the bulk of the hand-husked rice retained for home consumption is parboiled in the home by the growers. The importance of domestic parboiling may be noted from the fact that probably not less than two-thirds of the average annual production of parboiled rice is treated in the home. For domestic parboiling, the method is to put the paddy in a tin or a suitable container and cover it with water. The container is placed over fire and the water brought to boil. When the paddy grains have swollen a little and a few grains have burst, they are spread out on the floor to dry. Some modified forms of the process are also used.

For commercial parboiling, one method consists of steeping the paddy in water in cement tanks for one to three days, and then subjecting it to the action of steam in cylindrical containers for anything up to ten minutes. In another method, paddy is first placed dry in a cylindrical container and steam introduced for about one to five minutes. The paddy is then transferred to steeping tanks and left there for 18 to 36 hours, after which time a second application of steam for five to ten minutes is given. After such a treatment, the paddy in both the methods is spread out for drying. The third method which consists of applying heat to steeped paddy by roasting it with sand in shallow iron pans over a strong fire, prevails in some districts of Uttar Pradesh.

Parboiling generally gives a higher outturn of whole rice and improves the milling qualities of raw rice, although different varieties of rice respond very differently to parboiling in regard to the milling quality.

The cost of parboiling is included in the cost of milling, and is difficult to isolate. Inquiries made, however, show that it varies in different areas according to the nature of the process and the apparatus used. For instance, in Madras State, where parboiling by steam is customary, the cost is reckoned at about annas two per bag of paddy (one bag is equal to 1½ maunds), which means 16 pies per maund of paddy as against nine pies per maund in the the pre-War period.

HULLING

Hulling, the process employed for converting paddy into rice, is carried out either by a simple indigenous method entailing manual labour only, or by the use of power-driven machinery, the former accounting for about three-fourths of the rice produced in India.

Machine-milling. For hulling in power-driven mills, two main types of machinery are used in India. The first is the simple and comparatively cheap horizontal huller of a small size, and the second the more complicated plant known as the 'self-contained automatic sheller'. The handling capacity of the average

size huller, requiring up to 5 H.P. to drive it, ranges from 350 to 400 pounds of paddy per hour. The second type of milling machinery works automatically with the minimum of manual labour. It is highly efficient as it minimizes breakage, and bran is recovered without wastage. In spite of the relatively high initial cost, the self-contained milling plant is getting increasingly popular, mainly in Madhya Pradesh, Bombay and parts of peninsular India. The distribution of mills and hullers in the various states of India is given in Table 96.

TABLE 96. DISTRIBUTION OF MILLS AND HULLERS IN THE VARIOUS STATES OF INDIA

Name of the State	Mills	Hullers
Assam		249
Kerala	22	388
Orissa	88	N.A.
Madhya Pradesh	413	312
Bihar	148	620
West Bengal	403	5,000
Bombay	509	3,229
Erstwhile Hyderabad State	343	341
Andhra	759	2,802

Hand-pounding. There are a number of implements used in the different parts of the country for hand-pounding of rice. They are the pestle and mortar, wooden *chakki*, clay *chakki* and *dhenki.*

Generally, wooden, stone and clay *chakkies* are used only for dehusking paddy, while the pestle and mortar and *dhenki* are used for polishing dehusked rice, and also for the combined process of dehusking and polishing rice.

Dhenki is mainly used in Assam, West Bengal, Orissa, Bihar, some parts of Madhya Pradesh, Uttar Pradesh, the Punjab and Andhra, both for dehusking and polishing. The pestle and mortar is mainly used in Madras, Travancore-Cochin, Mysore, Hyderabad and Andhra, both for dehusking and polishing rice.

The cost of hulling by various processes in the different states is given in Table 97.

TABLE 97. COST OF HULLING BY VARIOUS PROCESSES IN DIFFERENT STATES

Name of the State	Milling or hulling (Rs. per maund)	Hand-pounding (Rs. per maund)
Assam	0 8 0 to 1 0 0	1 0 0 to 1 8 0
Kerala	0 12 0	1 4 0
Orissa	0 6 0	0 14 0
Madhya Pradesh	0 8 0 to 0 12 0	1 0 0
Bihar	0 8 0 to 0 13 0	1 4 0
West Bengal	0 8 0 to 0 12 0	1 8 0
Bombay	0 8 0 to 0 10 0	N.A.
Erstwhile Hyderabad State	0 4 0 to 0 6 0	1 0 0 to 1 8 0

The hullin goutturn is reckoned not only in terms of the total recovery of hullable products (rice, broken rice and bran), but also in the proportions of each. A normal crop of paddy, reasonably free from extraneous matter, should yield on hulling roughly 74 per cent. of hullable products. The recovery in the case of a fine variety is one to three per cent. less than that of a bold variety. The proportions of the various products, i.e. rice, broken rice and bran, vary according to the process used and the type or variety of grains. Parboiled paddy gives a higher outturn of hulled rice than raw paddy. Hand-pounding gives a higher recovery of rice than machine-milling. The proportion of broken rice resulting from hand-pounding is, however, higher than any machine-milled rice. The self-contained mills give less breakage than the hullers.

The percentage of normal recovery of rice from paddy in the various states of India is given in Table 98.

TABLE 98. PERCENTAGE OF NORMAL RECOVERY OF RICE FROM PADDY IN THE VARIOUS STATES

Name of the State	Mill or Huller	Hand-pounding
Assam	62·5	Slightly more
Kerala	67	70
Orissa	64	65 to 71
Madhya Pradesh	67·5	Slightly more
Bihar	64 to 65	66
West Bengal	67	70
Bombay	68	71
Erstwhile Hyderabad State	67	N.A.
Andhra	50 to 75	50 to 73

DRESSING AND COLOURING

In addition to the polish imparted to the rice kernels during machine-milling or hand-pounding, the grain receives further dressing or polishing for improving the appearance of the produce so that it may appear uniform, and to make detection of admixtures of foreign grains and mixtures of old and new rices difficult.

Turmeric or yellow and red ochre are used for giving rice an artificial colour, while substances like wheat flour, corn flour, talc, powdered rock salt, castor oil, groundnut oil and white mineral oil are used in different places to enhance the whiteness of the rice and give it a gloss or lustre. The colouring in parboiled rice is attained by prolonging the steaming.

CHAPTER 26

ASSEMBLING

India is a country predominantly of small holdings, and the assembling of produce from the fields constitutes one of the chief marketing services and is of special importance since it is through this process that the grower converts his produce into cash. The various persons or agencies engaged in the assembling of the rice crop—either as paddy or rice—may belong to one or the other of the following categories.

(a) Cultivators.
(b) Growers who also collect the produce of other cultivators.
(c) Landlords or *zamindars*.
(d) Village merchants or *banias*.
(e) Itinerant merchants or *paikars* and *farias*.
(f) Wholesale merchants or *kutcha* and/or *pukka arhatiyas*.
(g) Professional dehuskers.
(h) Rice mills' agents.
(i) Co-operative organizations.

The relative importance of the above agencies in the assembling of paddy and rice in the pre-war period is brought out in Table 99.

TABLE 99. RELATIVE IMPORTANCE OF VARIOUS AGENCIES IN THE ASSEMBLING OF PADDY AND RICE

Agency	Paddy in terms of rice per cent. of marketable surplus	Rice	Total
Growers	6·8	6·8	13·6
Landlords	5·8	1·0	6·8
Village merchants	7·9	7·3	15·2
Cultivators collecting produce of others	1·3	0·8	2·1
Itinerant merchants	8·1	7·3	15·4
Professional dehuskers ..	nil	3·3	3·3
Wholesale merchants	14·1	5·1	19·2
Rice mills	13·1	nil	13·1
Co-operative societies	0·1	nil	0·1
Total	57·2	31·6	88·8
Direct distribution in villages & *mandis*	3·8	7·4	11·2
Grand total (marketable surplus)	611	39	100·0

It may be stated that of the 61 per cent. of the total marketable surplus marketed in the form of paddy, 57.2 per cent. gets assembled at the wholesale assembling markets. The largest share amounting to 14.1 per cent. of the total marketable surplus is handled by wholesale merchants, making direct purchases in the village through their agents. The rice mills follow closely with 13.1 per cent. of the total marketable surplus, practically all of which is also procured in the rural areas from the producers direct. Itinerant traders and village merchants jointly accounted for another 16 per cent. in roughly equal proportions. Growers and landlords rank 4th and 5th, respectively ; the respective shares of these two agencies being 6.8 per cent. and 5.8 per cent. of the marketable surplus. Cultivators collecting the produce of other growers play a very small part in the assembling of paddy, and handle only 1.3 per cent. of the marketable surplus. Co-operative organizations handle an insignificant percentage of the marketable surplus.

With the exception of a very small proportion used for the manufacture of parched products, practically the entire volume of paddy, assembled or ultimately purchased by wholesale merchants and rice mills in addition to the quantities acquired by these agencies directly from growers and others in the rural areas, is converted into rice by the mills.

The remaining 3.8 per cent. of paddy does not pass through the assembling stage, being disposed of mainly by growers and peripatetic traders in the villages *hats* or *shandis* to retailers, grain parchers and direct consumers.

The entire aspect of assembling, however, changed during the period of controls. The abnormal situation caused by World War II necessitated the imposition of control over the movement and distribution of a numbr of essential commodities, including foodgrains. The normal channels of trade were, therefore, considerably modified, and the normal assembling agencies ceased to play their usual part. Large sections of the population were brought under the statutory and non-statutory rationing, and to fulfil the rationing requirements, the Civil Supplies Departments in the various states undertook the procurement of the necessary foodgrains. It is true that the Civil Supplies Department employed some of the traditional and normal agencies like *beoparis*, *arhatiyas* and the wholesale merchants. as purchasing agents or sub-agents, but their *modus operandi* and frame of business was considerably regulated by the Government.

The exact nature of the restrictions, however, varied in the different states, depending upon local conditions. The share of the normal assembling agencies underwent varying changes in the different states. In West Bengal, it is estimated that more than 80 per cent. of the marketable surplus continued to be handled by *beoparis*, *arhatiyas* and mills, acting as agents of the Government. In Orissa, 70 per cent. of the market arrivals were reported to have been assembled by the Government through the various agents who collected paddy and rice directly or through the sub-agents at statutory prices fixed by the Government for different grades and areas. In Mysore, after the Harvest Acquisition Order, the monopoly procurement of paddy and other foodgrains commenced with effect from December, 1943, and the Government became the sole assembling agency, ousting every other normal agency from the field. A peculiar system obtained in Assam, where the assembling

work was entrusted to a private firm which acted as a Government procurement agent, both for supplying paddy for the Armed Forces stationed in Assam, and for meeting civilian requirements. This continued up to 1946, when the Government itself took up the procurement work to fulfil the entire civilian demand, and complete its export quota as laid down in the Government of India's basic plan. In Bombay State, assembling of paddy and rice was done by revenue officers directly, and in certain areas, through millers who were licensed to purchase paddy on Government account at fixed prices, and to sell the rice to the Government at prescribed prices.

The Government also made use of co-operative societies for procurement in certain states such as Madras and Bombay.

After the decontrol in July, 1954, the normal agencies engaged in the assembling of paddy and rice as in the pre-War period have been at work, and there has not been any appreciable change in the relative importance of each agency in assembling the produce.

MARKETS

The markets in India may be broadly classified as: (i) primary markets known as *hats* at the village level; (ii) the secondary markets known as *mandis* or *gunjs* in urban and township areas; and (iii) terminal markets in big town and cities where the produce is finally pooled for consumption and distribution in the inter- or inter-state trade or for export abroad.

The primary markets generally serve the producers residing within a radius of five to 25 miles from the market and are held weekly or bi-weekly. Amenities ordinarily available in secondary markets are conspicuous by their absence. Transactions are carried out on an arbitrary basis and these are often biased in favour of the buyers. These primary markets handle both rice and paddy.

In contrast to primary markets, the secondary markets known as the *mandis* or *gunjs* provide a permanent place for daily transaction of wholesale business. These markets are situated in urban centres often connected by rail and metal roads and serving a radius of something like 20 miles and more. All the marketing functionaries are found to operate in these secondary markets.

There are reported to be 543 important markets in the principal rice-growing states, handling rice and paddy. These markets also handle other commodities. Out of these 543 markets, only 222 are regulated. The grouping of these markets on the basis of the quantities handled is given in Table 100.

REGULATED MARKETS

To ensure better buying and selling of agricultural produce and with a view to protecting interests of producer-seller by reducing opportunities for malpractices, various State Governments have passed the Agricultural Produce Markets Acts and established, what are known as, regulated markets. The broad features of these markets are: (i) clear definition of market charges, reduction of excess charges and prohibition of unauthorised additions to them; (ii) regulation of market practices; (iii) licensing of marketing functionaries including buyers, brokers and weighmen; (iv) use of standard weights and measures; (v) arrangement for settlement of dis-

TABLE 100. GROUPING OF MARKETS ON THE BASIS OF THE QUANTITY HANDLED

Quantities handled					Number of Markets: Regulated	Number of Markets: Unregulated
Below	5,000 mds.				117	53
Above	5,000 mds., but below 10,000 mds.				28	14
Above	10,000	mds., but below 25,000			25	51
,,	25,000	,,	,,	50,000	16	75
,,	50,000	,,	,,	75,000	10	24
,,	75,000	,,	,,	1,00,000	2	14
,,	1,00,000	,,	,,	2,00,000	11	39
,,	2,00,000	,,	,,	3,00,000	4	20
,,	3,00,000	,,	,,	5,00,000	7	22
,,	5 lakh maunds				2	9
				Total	222	321

putes regarding quality, weighment, deduction, etc. ; (vi) sale by open auction or open agreement ; (vii) appointment of market committees fully representative of growers, traders, local authorities and the Government ; (viii) arrangement for display of reliable and up-to-date market information in the market yard ; (ix) control by the Government over the markets and market committees. Of the 13 states in the Indian Union, all excepting Uttar Pradesh, Rajasthan, Bihar, West Bengal and Assam have passed the relative Acts and established regulated markets. The states not having passed the Acts, are expected to do so by the end of the Second Five Year Plan. These markets besides regulating agricultural commodities also regulate products of livestock and animal husbandry, forests, etc.

Market functionaries. *Arhatiyas* or *aratdars* (commission agents), *dalals* (brokers), *tolas* (weighmen) and *palledars* or *hamals* (labourers) are the four important market functionaries.

There are two kinds of *arhatiyas*, namely, *kutcha* and *pukka*. The former is a person of small means acting mainly as an intermediary between the primary producer and the buyer in the wholesale assembling market, and receiving commission for his services from the seller or the buyer, or sometimes from both. The *pukka arhatiyas* who often function as wholesale merchants also buy produce in the assembling markets or sell produce at consuming centres on behalf of their clients in other centres. The functions of a *kutcha* or a *pukka arhatiya* may both be carried out by the same person, who is then known as *kutcha-pukka arhatiya*.

The main function of a *dalal* (broker) is to bring buyers and sellers together.

Tola (weighman) may be an employer of the *arhatiya* (commission agent) employed on a salary or commission basis, or may work independently for a fee

known as *tolai*, charged on the quantity of the produce weighed. In regulated markets, all *tolas* are licensed, and the scale of charges fixed.

Palledars or *hamals* are labourers, who carry on operations like loading and unloading in the carts, wagons, lorries, etc., stacking bags, assisting in weighing and cleaning and dressing the produce.

Market practices. Though not differing greatly in general principles, market practices vary from place to place and have acquired recognition by long usage and tradition. Market legislation in the states of Bombay, Madras, Madhya Pradesh and Andhra Pradesh, has improved matters to a great extent by fixing market charges and licensing the various functionaries. But such enactments have not yet been adopted on a sufficiently large scale. The market *panchayats* or associations of traders in certain markets have helped in some measure to standardize market procedure ; but here too, the extent of organized trade, as far as indigenous varieties are concerned, is not large.

Paddy is usually brought to the assembling market in bulk and rice packed in gunny bags. On arrival at the market the paddy may be heaped in front of or near the *arhatiya's* shop or left in the cart. Rice bags are frequently unloaded and stacked. The *arhatiyas* negotiate sales on behalf of the seller. The transactions generally take place in the morning, the latter part of the day being taken up in weighing and settling accounts. Prices may be settled by giving offers (i) under cover, (ii) by auction or (iii) by open offer or private treaty. In the 'cover' system the buyer indicates the prices he is prepared to pay by clasping the hands of the *arhatiya* under cover of a cloth and pressing or mainpulating the fingers. The seller is usually consulted by the *arhatiya* before he accepts the offer. In the auction system, the *arhatiya* auctions the produce at a particular part of the day, when all the buyers assemble near the produce. For sales by open offer or private treaty, the buyers may give their offers by going to the seller's agent at any time or to the *dalal* when he comes round with his samples.

MARKET CHARGES

When paddy or rice is brought to the markets for sale, a number of deductions, either in kind from the produce or in cash from the sale proceeds thereof, are made. In some cases, the buyers have also to bear some charges in addition to the price of the produce.

The first charge, which the produce to be sold in the market is subjected to even before entering the market, is the toll tax. In private-owned markets, the owner or the lessee generally levies a toll on all produce handled in the market, while the municipalities in many cases levy an octroi or terminal tax on the agricultural produce entering municipal limits. The insistence on municipal taxes has, in several cases, resulted in driving out the markets outside the municipal limits. The next charge is the commission or *arhat* or *dalali* paid to the *arhatiya* and *dalal*, respectively, in return for their services. They are payable either by the seller or the buyer, or sometimes by both.

Besides the *arhat* and *dalali*, payment in cash or in kind has to be made to the labour employed for loading, unloading, cleaning, weighing or measuring the produce and stitching of bags, etc. These charges, which vary in different markets,

depending on the local rates of labour and the extent of services rendered, are generally borne by the seller but the cost of removing the produce after weighment to his godown is, in most cases, met by the buyer.

Apart from the payments to market functionaries, deductions in kind, e.g., *dhalta* (quantity allowance), *karda* (deduction on account of refraction) and *dane* are also made from the seller in order to compensate the buyer for loss in weight on account of impurities, driage, etc. These deductions are made whether or not the condition of the produce justifies the allowance. Deductions are also made for contributions for charitable objects, e.g., gowshalas, temples, schools, etc. These are payable either exclusively by the seller or both by the buyer and seller. In addition to the above-mentioned deductions, a number of other allowances are levied which in aggregate often assume considerable proportions. The charges levied under different heads vary enormously in different markets. Table 101 gives the average marketing charges in assembling markets in some important states.

FINANCE

The village merchant, who in addition to trading in commodities carries on money-lending also and is styled as the *bania* or *mahajan*, is a very important source—often the only source—of credit for the cultivator. In many cases, however, landlords also play the role of the financier. Loans of grain are generally advanced on the *savai* (1¼) system, and in some cases on *dorhi* (1½) system, being repayable at the time of harvest with an additional one-fourth or one-half, as the case may be, of the quantity borrowed. Cash loans for short periods are advanced on the personal security of the borrowers ; the rate of interest varies according to the financial standing of each borrower and in different areas. For example, in West Bengal, no interest may be charged on cash loans provided the cultivator makes the reduction in kind, in which case the price of paddy (in terms of per maund or a fixed quantity in liquidation of the debt) for delivery at harvest time is stipulated much lower than the expected harvest price. In Bombay, the usual rate of interest is 18 to 24 per cent. with the obligation to sell the produce to the creditor at harvest. Often, a cash loan at the time of advance is commuted into a grain loan at a price considerably lower than the expected harvest price and a fixed quantity of produce delivered at the harvest. In Uttar Pradesh, the rate of interest charged by the village money-lenders in the rice tracts is generally 18.75 per cent. to 37.5 per cent. per annum, the loan being repayable at harvest in the form of produce. In Bihar, however, there are a number of grain *galas* which are primarily grain societies concerned with giving loans of grain to members particularly for sowing purposes. These *galas* are in some cases under the Central Co-operative Banks but mostly operate independently.

From the above description of the short-term finance of the rice grower, it is clear that in addition to paying an excessively high rate of interest, even allowing for the serious risk which the creditor may be running, the debtor has to part with a considerable proportion of his produce soon after the harvest at very low value, in comparison with what he would have obtained had he been in a position to market independently.

TABLE 101. AVERAGE MARKET CHARGES ON PADDY AND RICE IN ASSEMBLING MARKETS

(IN PERCENTAGE OF VALUE OF GOODS)

	Madras (paddy)	Uttar Pradesh		Orissa		Bihar		Madhya Pradesh (Rice)	Bombay (Rice)	Andhra Pradesh			
										Paddy		Rice	
		Paddy	Rice	Paddy	Rice	Paddy	Rice			Regu-lated	Un-regulated	Regu-lated	Un-regulated
PAYABLE BY SELLERS													
1. Municipal tolls, taxes, etc.	..	0.500	0.578	..	..	..	0.573	0.427	..	0.521	0.521	0.370	0.297
2. Handling up to the point of weighment or measuring	1.078	0.219	0.458	0.234	0.667	0.401	0.266	0.479	0.193	2.193	1.438	1.208	1.187
3. Quantity and weighment allowances	..	4.854	2.219	..	..	0.906	0.625	..	..	..	..	..	0.828
4. Commission	..	..	0.750	..	0.875	1.406	0.922	1.203	1.500	1.250	0.750	1.250	3.417
5. Brokerage	0.932	1.552	0.708	..	..	..	..	..	..	..	..	..	..
6. Charities	0.412	0.073	0.214	0.349	0.109	0.099	0.109	0.484	..	..	0.989	0.062	0.099
7. Miscellaneous	..	3.322	2.135	0.250	..	0.401	1.083	..	..	..	..	..	..
Total	2.422	10.520	7.062	0.833	1.651	3.213	3.578	2.593	1.693	3.964	3.698	2.890	5.828

TABLE 101—*Concluded.*

	Madras (paddy)	Uttar Pradesh		Orissa		Bihar		Madhya Pradesh (Rice)	Bombay (Rice)	Andhra Pradesh			
										Paddy		Rice	
		Paddy	Rice	Paddy	Rice	Paddy	Rice			Regulated	Unregulated	Regulated	Unregulated
PAYABLE BY BUYERS													
1. Handling from the point of weighment up to the buyer's godown	0.620	0.781	0.698	0.766	..	..	..	1.448	0.771	..	0.922	0.453	0.453
2. Commission	0.614	2.344	1.375	..	..	..	..	0.333	1.500	..	..	..	..
3. Brokerage	0.620	0.250	..	..	..	..	..	..	..	..	..	..	..
4. Charities	0.614	..	0.062	..	..	..	..	..	..	..	..	..	0.375
5. Miscellaneous	..	..	0.375	..	..	..	..	..	..	..	..	..	..
Total	2.468	3.375	2.510	0.766	..	..	..	1.781	2.271	..	0.922	0.453	0.828
Grand total	4.890	13.895	9.572	1.599	1.651	3.213	3.578	4.374	3.964	3.964	4.620	3.343	6.666

Wholesale merchants and commission agents advance funds on personal security to village merchants and *beoparis*, the rate of interest on such loans generally being from nine to 12 per cent. Advances are also given on the security of produce stocked with wholesale merchants and commission agents, generally to the extent of 75 per cent. of the value of the goods at the current market rate. Joint-stock banks also give loans to merchants on the produce stocked under security of their lock and key. The co-operative societies, in most cases, function as purely credit institutions and do not give advances on the security of produce, but a few co-operative credit and sale societies for paddy and rice advance money on the security of produce, the rate of interest varying from six to nine per cent.

CHAPTER 27

CLASSIFICATION, GRADING AND STANDARDISATION

Quality factors in rice and their more important trade description with the physical characteristics, have already been given in the earlier chapter under the three major categories of: (i) conformation, *viz.*, fine, medium and bold, (ii) raw and parboiled; and (iii) machine-milled and hand-pounded. The factors on which the commercial classification of rice is based need not, therefore, be repeated here. For greater convenience, however, it may be useful to present in a tabular form a list of the main trade descriptions classified in accordance with the above factors, the fine category being subdivided into long and short, and giving the state and the district or districts of production. It should, however, be borne in mind that a certain amount of overlapping occurs in production and that, in consequence, the districts named are only those in which the variety in question is chiefly grown. A list of some of the important trade descriptions, together with index of the areas where they are grown is given in Table 102.

TABLE 102. CLASSIFICATION OF SOME IMPORTANT COMMERCIAL VARIETIES OF RICE

Varieties	Trade name	Area of production	
		State	District
1. FINE A. Long fine			
(*i*) Raw	*Dehra Dun*	Uttar Pradesh	Dehra Dun
	*Basmati**	do.	Naini Tal
	Hansraj†	do.	Bareilly
	Raimunia	do.	Saharanpur
	Seeta (*Patnai*)	West Bengal	24-Parganas Midnapore Hooghly
(*ii*) Parboiled	*Patnai*	West Bengal	24-Parganas Midnapore Hooghly
	Kalambank (*Patnai*)	Orissa	Balasore
	Balam	West Bengal	24-Parganas Hooghly
	Kalamakatti	do.	West Dinapur Bankura

*Scented

†Hand-pounded

TABLE 102—*Continued.*

Varieties	Trade name	Area of production	
		State	District
	Kalamkatti	Bihar	Purnea Santhal-Parganas Manbhum
	Saharanpur Sela	Uttar Pradesh	Saharanpur
	Raimunia	do.	do.
B. Short fine			
(i) Raw	*Kamod*	Bombay	Gujarat districts
	Kolomba (Zenia)	do.	Thana
	*Jiresal**	do.	Poona
	Kolpi	do.	Maval
	*Kalikamod**	Madhya Pradesh	Bhandara
	*Chhatri**	do.	Seoni-Chhindwara
	*Chinoor**	do.	Balaghat Bhandara
	*Baspatri**	do.	Raipur, Drug
	G.E. B. 24 *Khichili* or *Khichidi Samba*	Madras	West and East Godavari, Kistna, Guntur, Kurnool, Anantapur, North & South Arcot, Chingleput
	Krishnakatukulu	do.	West and East Godavari, Visakhapatnam
(ii) Parboiled	*Sitasal*	West Bengal	Midnapore, Hooghly, 24-Parganas
	do.	Orissa	Mayurbhanj, Balasore
2. MEDIUM			
(i) Raw	*Begami*	Punjab	Amritsar
	Sone	do.	do.
	Anjana	Uttar Pradesh	Moradabad, Bareilly
	Sondhi	do.	Etawah
	Didai	do.	Basti Gorakhpur Gonda
	Anji	do.	do.
	Rambhog	do.	do.
	Luchai *Budhiabako* *Samundarasok*	Madhya Pradesh	Raipur Bilaspur Drug

TABLE 102—*Continued.*

Varieties	Trade name	Area of production	
		State	District
2. Medium— (*i*) Raw (contd.)	*Kersail*	Assam	Goalpara Sibsagar
	Ambemohar **	Bombay	Karnatak
	Sutersa,	do.	Gujarat
	Red Sirumani	Madras	Tanjore South Arcot Chingleput
	White Sirumani	Madras	Tanjore South Arcot Chingleput
	Akkulu	do.	West and East Godavari Kistna
	Sadai Samba	do.	Trichinopoly South Arcot Coimbatore Salem
	Attragada	do	West Godavari Kistna Guntur
	Molagolukulu	do.	Nellore
(*ii*) Parboiled	*Dudhraj* *Dukhani*	Bihar	Champaran Saran Muzaffarpur Darbhanga Purnea
	Saldhenti *Kankerbija*	Orissa	Sambalpur States of Bamra Raigarh Sonpur Patna
	Dudhkalma *Jatakalma*	West Bengal	Burdwan Bankura
	Agra	do.	Burdwan Bankura Midnapore Hooghly
	Indrasail	West Bengal	Dinajpur Murshidabad
	Banktulsi **	do.	24—Parganas Burdwan

**Border line cases

TABLE 102—*Concluded.*

Varieties	Trade name	Area of production	
		State	District
2. Medium-(Contd.) (ii) Parboiled (Contd.)	*Red Sirumani*	Madras	Tanjore
	White Sirumani	do.	South Arcot, Chingleput
	Nekiradhan, *Malsira*, *Latisal*	Assam	Golepara, Sibsagar
(3) Bold—			
(i) Raw	*Ghona*	Punjab	Amritsar
	Banki, *Sathi*	Uttar Pradesh	Hardoi, Unao, Sitapur, Barabanki
	Pahari	do.	Etawah
	Dhani	do.	Saharanpur
	Bhadian	do.	Gorakhpur, Basti, Gonda, Azamgarh
	Gurmatia	Madhya Pradesh	Raipur, Drug
	Pattni	Bombay	Ratnagiri
	Kusuma	Madras	Kistna, Guntur
	Konamani	do.	West and East Godavari, Kistna, Visakhapatnam
	Kodai	do.	Madurai, Ramnad, Tinnevelly
(ii) Parboiled	*Kazla*	West Bengal	Nadia, Midnapore
	*Satraj**	Bihar	Saran, Champaran, Shahabad, Muzaffarpur
	Kuruvai	Madras	Madura, Ramnad, Tinnevelly

*Hand-pounded
**Border line cases

SPECIMEN OF AN AGMARK LABEL
USED FOR GRADED RICE

[Name of variety to be stamped in this space.]

AGMARK

RICE

SPECIAL QUALITY

Sl. No.

Nett weight ______ of the ______ crop

Graded and packed by ______________
Place of grading ______________
Date of packing ______________
____
____

This label is the property of the Agricultural Marketing Adviser to the Government of India.

Fig. 44. Agmark label used for graded rice

CLASSIFICATION IN PERIODS OF CONTROLS

During the War and periods of controls, when procurement and distribution of foodgrains were brought under Government authority, paddy and rice were classified in various states according to the individual state's local conditions. This classification was not uniform in all the states, and there were wide variations from state to state, both in respect of the number of classes or categories recognised, and in regard to the nomenclature employed. In one state (Orissa, for instance), rice was classified on the basis of size as follows.

(i) Coarse—breadth above 2.75 mm.

(ii) Fine—breadth above 2 mm. and below 2.75 mm.

(iii) Superfine—breadth 2 mm. or less.

Different prices were paid for different classes of rice.

In another state (Bombay), the classification was as, (i) Superior, (ii) Medium and (iii) Inferior. In the same State, in the producing areas, an altogether different classification was followed, such as:

(i) Superior sort No. 1.

(ii) Superior sort No. 2.

(iii) Inferior sort No. 1.

(iv) Inferior sort No. 2.

Again, in another state (Uttar Pradesh), rice was classified into Grades 'I', 'II', 'III' and 'IV'.

GRADING AND STANDARDISATION

Existing practices. The methods adopted in grading rice may either be mechanical or manual. The former system is invariably employed in the 'self-contained' or 'automatic huller' type of rice milling plant, as it is an integral part of the machinery. Manual grading is accomplished by different kinds of sieves in different areas, and by the winnowing tray method according to local usage. The types of sieves used lack uniformity in construction and size of mesh. Broadly, speaking, the highest grade of rice is regarded as being one which is retained by (or fails to pass through) a seive with 7 to 8 meshes to a linear inch. A rice which passes through an 8-mesh seive, but is retained by a 9-mesh is considered to be of the Grade II and so on. The subdivision into grades is naturally a matter of choice and also depends on market considerations.

Sale on samples. On account of the almost innumerable varieties of rice grown in India, and in the absence of any uniform grades of standards of quality, the great bulk of internal rice trade is conducted on the basis of samples, values being assessed by visual examination only, that is to say, by assessing characteristics such as translucency or opacity, colour, polish, proportion of broken grains present in the sample, etc., before any purchase is made. But all the same, no standard scales of allowances or deductions for the various impurities or defects found in rice have been recognized in any part of India.

Where sales of rice are made to comparatively distant consuming markets within the country, samples are not always sent for each transaction, particularly in the case of reputed varieties handled by well-known firms, many of whom may have

their own selling agents in different selling centres. In such instances, a few samples may be exchanged early in the season to give prospective clients some idea of the quality of the current year's crop. Subsequently, business may be done on the basis of trade descriptions only, provided the relations between the parties concerned have been mutually satisfactory in the past. Occasionally, large buyers maintain their own agents in important producing centres or their representative may pay special visits to the supplying markets to inspect the quality of the produce and make direct purchases.

In view of the large number of varieties involved, buying on sample, will continue until the different varieties are put on the market in the standard grades.

The Agmark Scheme. There are no recognized universal standards for rice applicable throughout India, and quality factors cannot everywhere be translated into terms of price by any precise formula. Nor is it possible to ascribe to each individual quality factor a definite proportion of the total price difference which may exist within two grades of rice of the same commercial variety, or between two different varieties. The above is due to the highly localized nature of the markets for certain types of rice, owing to the fact that the degree of importance attached to each quality factor by consumers in different parts of the country varies widely. For instance, a long, slender, fragrant rice such as the highly priced *Basmati* variety grown in Uttar Pradesh and the Punjab, would not be appreciated by the main body of consumers in South India, while a parboiled, hand-pounded rice of yellow or reddish colour, popular in West Bengal, Orissa or Bihar, would hardly be prized for edible purposes by a large section of consumers in northern India.

With the ultimate object of bringing about same measure of uniformity in the innumerable and undefined grades or qualities in which rice is normally put on the markets, measures have been taken under the Agricultural Produce (Grading and Marking) Act, 1937, to draw up standard grade specifications in respect of a number of well-known commercial descriptions.

Briefly stated, the Agmark Scheme for Rice operates as follows:

In order to fix the type and the permissible tolerances in respect of each factor, a large number of samples of each variety intended to be graded is obtained from the trade and their physical characteristics examined. Care is taken to select samples of representatives of the two, three or four better grades normally marketed, as it is considered undesirable to apply the Agmark to inferior produce. Each variety is covered by a separate schedule, defining in each case the limits of tolerance under items (a) to (g), and general characteristics under items (h) and (i) below.

(a) Foreign matter other than rice.
(b) Broken grains.
(c) Fragments.
(d) Other varieties including red grains.
(e) Damaged or discoloured grains.
(f) Weevilled grains.
(g) Chalky grains.
(h) Thousand-kernel weight.
(i) Size of grain as reflected in length and breadth.

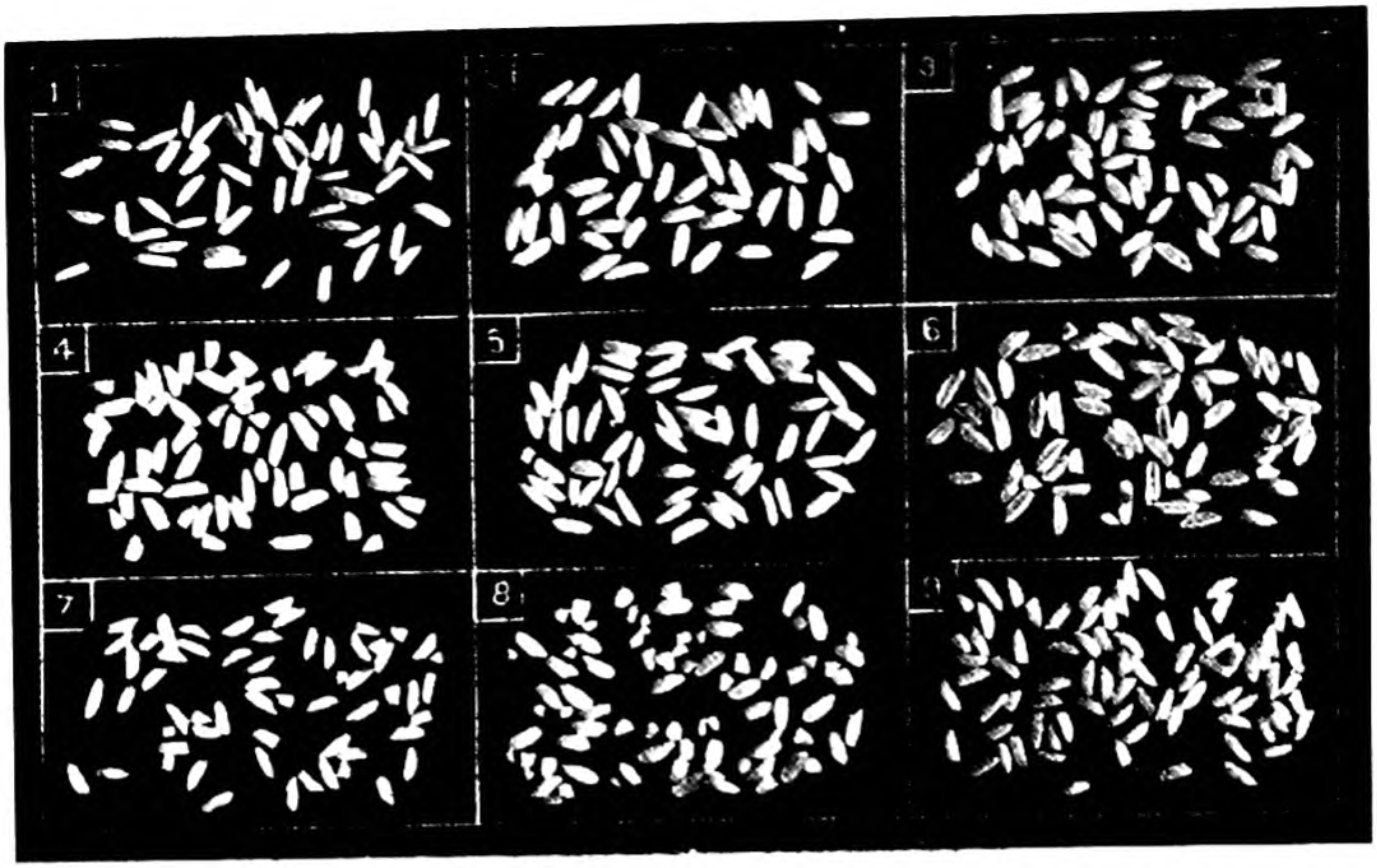


Fig. 45. 1. Parmal (raw)—Punjab. 2. Jhona (raw)—Punjab. 3. Sone Latera (raw)—Punjab. 4. Amritsar Mota (raw)—Punjab. 5. Gujranwala Basmati (raw)—Punjab. 6. Daudzai (parboiled—N.W.F.P.). 7. Chinncor (raw)—(M.P.). 8. Gurmatia (raw)—(C.P.). 9. Baspatri (raw)—(M.P.)

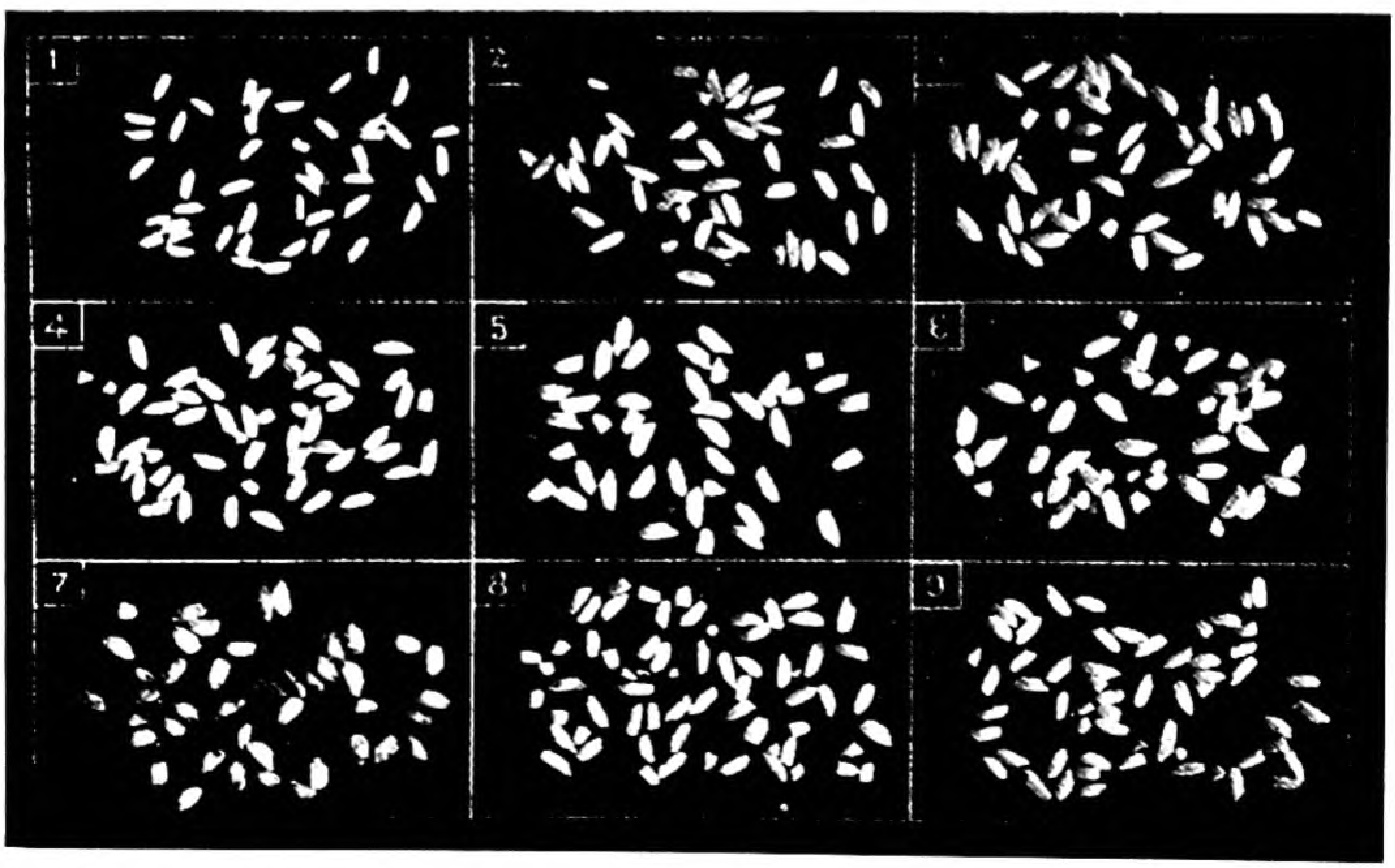


Fig. 46. 1. Zinnia (raw)—Bombay. 2. Jiresal (raw)—Bombay. 3. Kamod (raw)—Bombay. 4. Khichidi (raw)—Hyderabad. 5. Kusuma or Ramsagar (raw)—Hyderabad. 6. Kaddy White (raw)—Mysore. 7. Samba (parboiled)—Travancore. 8. Kangni (raw)—W. Pakistan. 9 Sugdasi (raw)—W. Pakistan

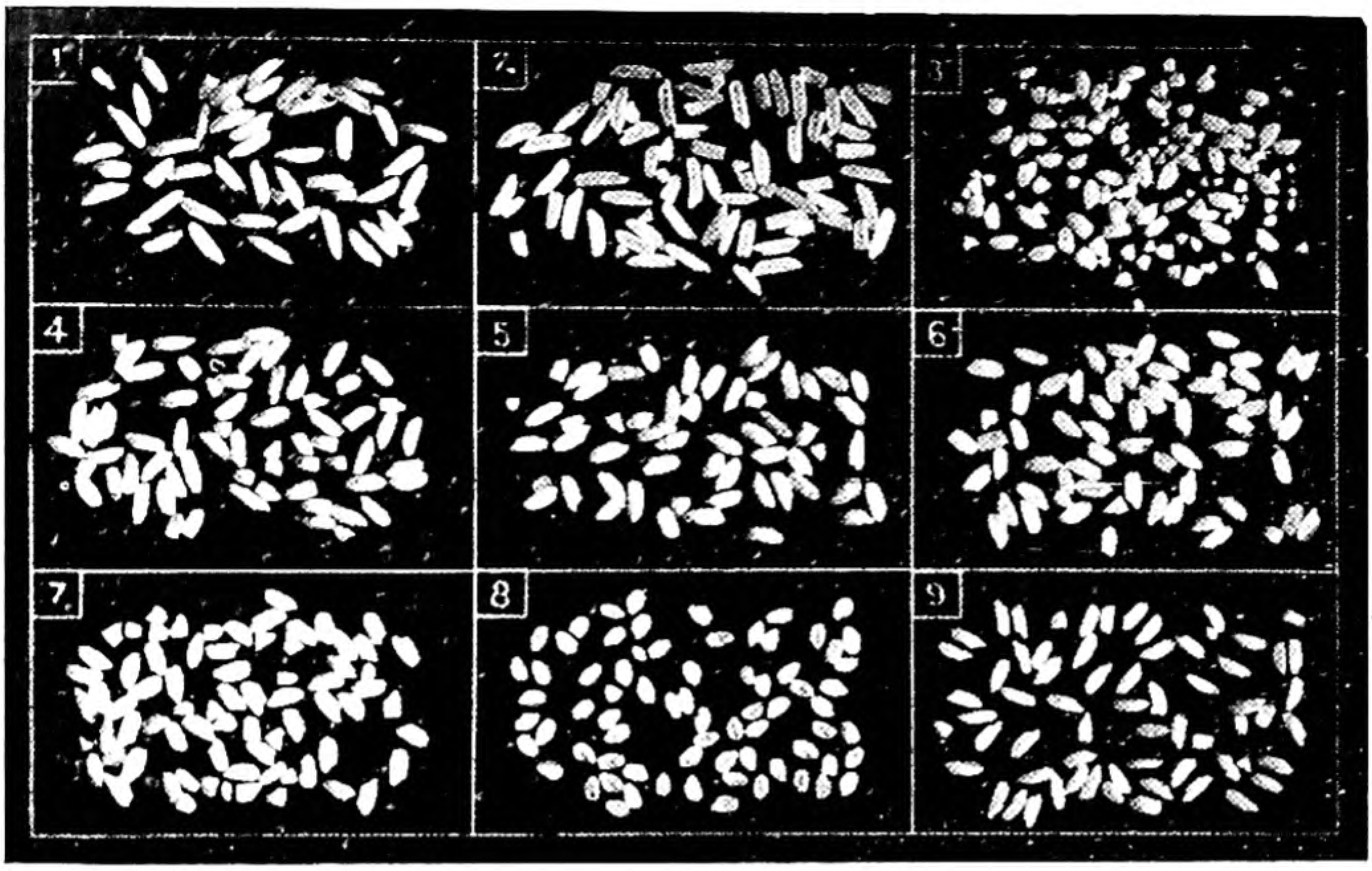


Fig. 47. 1. Kalamdan (parboiled)—Bihar. 2. Kalambank (parboiled)—Orissa. 3. Rathachudi (raw)—Orissa. 4. Saldhenti (parboiled)—Orissa. 5. Mota (raw)—Orissa. 6. Molagolukulu (raw)—Madras. 7. Nellore Samba (raw)—Madras. 8. White Sirumani (parboiled)—Madras. 9. G.E.B. 24 (raw)—Madras

The samples having been analysed and the various determinations made under the quality factors, the appropriate tolerances are laid down expressed as percentages by weight. Reference is next made to the trade interests concerned before initiating any grading work so that the tolerances fixed may be assured of their practicability by securing the full approval of the millers and merchants, as well as the producers and the co-operative sales organizations, where such exist.

The tentative specifications are then worked for some period before finally notifying the same in the Government of India Gazette, as required by the Act.

The experimental period over, the results of grading and marking under the Agmark Scheme are reviewed and changes, if any, introduced into the original draft specifications which are then duly notified in the revised final form. Every label used for graded rice is serially numbered, in addition to carrying the name of the packer and the packing centre. Thus, it is comparatively a simpler method to trace any consignment or individual bag as detailed records are maintained of the serial number of labels issued to authorised packers and the number actually used on different dates or periods for affixing to the containers.

The Agmark Scheme is entirely voluntary, and it is not obligatory on holders of certificates of authorization to grade and mark all their output or turnover. Only such quantities need to be put under the Agmark as fall within the limits of tolerance specified against one or the other of the grade designations.

Presently, grade specifications for the following varieties have been laid down.

1. Dehra Dun *Basmati* (raw milled)
2. Saharanpur *Basmati Sela* (parboiled)
3. *Nellore* or *Molakolukulu* (raw) (hand-pounded as well as milled)
4. *Kothamalli Samba* or *White Sirumani* (raw milled)
5. *Kaisipichodi* or *Bangarutheega* (raw milled)
6. *Sirumani* or *Red Sirumani* (parboiled milled)
7. *Krishnakatokulu* or *Maharajabhogam* or *Akusanam* (raw milled)
8. *Atragada* or *Ramasagara* (raw milled)
9. *Nellore Samba* (raw milled)
10. *Kusuma* (raw milled)
11. *G.E.B. 24 Kichli* or *Kichdi Samba* (raw milled)
12. *Delhi Bhogam* (raw milled)
13. *Korangu Samba, Kattai Samba* or *Arai Samba* (parboiled milled)
14. *Nellore Samba* (parboiled milled)
15. *Muthusamba* or *Kothamalli Samba* or *White Sirumani* (parboiled milled)

The first experiment in grading was initiated in 1939 in Dehra Dun in Uttar Pradesh, in an area noted for the production of *Basmati*, the scented fine rice. Similar experimental rice grading stations were established in Madras and other states.

The grading of rice, which had been started in January, 1939, was stopped throughout the country in 1944 due to the various restrictions imposed consequent upon World War II. After the coming of the War and controls, a rapid deterioration in quality set in at most centres of production. This led to the rice grading

scheme being put under departmental control, so that the actual testing, grading and marking could be done by the trained subordinates in the Marketing Section. For this purpose, revised War quality specifications were also drawn up.

Rice has been decontrolled only very recently, and the ban on its movement removed in 1954. The grading of rice has been revised since 1954 and is done on the War quality specifications, but efforts are being made to re-adjust the whole classification in the changed circumstances, viz., return of normal conditions both in the production pattern and marketing.

With regard to imported rice, the Government of India has not fixed any specifications. The Indian purchases from exporting countries like Burma, Thailand, etc., are chiefly on specifications laid down by those countries and mutually fixed limits of tolerance subject to imposition of cuts in rates, etc.

CHAPTER 28

CONSERVATION

The bulk of the rice crop held in the villages is stored in the form of paddy, as the grain keeps far better and for a much longer period in that condition. Deterioration is particularly marked in the case of hand-pounded rice owing to the development of rancidity in the oil-bearing bran layer surrounding the endosperm, which the hand-husking process only partially removes from the kernel. Cultivators, therefore, prefer to keep their produce in the form in which it is harvested and husk it as and when required. Where rice as such is kept for domestic consumption, it is generally stored in earthen pots or home-made bins and the quantities involved are rarely more than a few days' supply.

A large variety of receptacles of infinitely variable capacities are used for the storage of paddy. These are described below.

Receptacles made of Plaited Straw, Split Bamboo, etc. Home-made containers of straw, bamboo splits, cotton, mid-ribs of toddy palm leaves, etc., are widely used for storing paddy. The capacities of such containers are almost infinitely variable according to the amount of produce retained on the holding. Their shape may be conical, cylindrical or spherical according to the dictates of custom and convenience.

Receptacles made of Mud or Brick-work. These are of a permanent or semi-permanent character, and are commonly known as *kothis*, being mainly used in Uttar Pradesh, Bihar and Madhya Pradesh. In addition to being used for paddy, other kinds of produce could also be stored in them. The *kothi* is usually rectangular or conical in shape, and supported on mud props. Larger masonry structures known as *kothis* are also used for storing paddy by some big landlords in northern India. In Mysore, many landlords possess masonry cubicles called *kanajas* in which they keep their paddy and other produce-stocks. Some of these *kanajas* are constructed above ground level while others are built below ground level.

Wooden Receptacles. Wooden bins of various dimensions are used by cultivators for storing paddy, especially in Assam, Bombay, Mysore and Kerala. In most instances, the bins are merely boxes, chiefly made of local wood. The type of receptacle, found in Kerala, however, is unique and calls for a special mention. In this State, the average cultivator's home contains, as an integral part thereof, a specially constructed small safe room known as *arah*. The *arah* is generally supported on a raised platform, two to three feet above the general floor level to safeguard the contents against dampness. It is interesting to note that such *arah* contains a small bin also made of wood used exclusively for the storage of seed paddy, and known as *pathazam*. While the capacity of the *arah* may range from one to 20 tons, that of a *pathazam* is usually anything from ten to 25 maunds.

Pits. These form the most popular method of storing paddy in Orissa, but the pit system is also in vogue in Madras and some parts of Bihar. In Orissa, the

pits used for paddy storage are generally lined with a plastering of cow-dung. A layer of straw is placed on the bottom of the pit before filling, and another on the top of the grain over which a final coating of mud plaster is laid. The method adopted in Madras is a little more elaborate as the sides of the pit are generally lined with a fabrication of straw.

Miscellaneous. In the Punjab principally, and to a small extent in Uttar Pradesh, paddy is stored in bulked heaps on the floor of rooms in the grower's home or godown. In many parts of India, especially in the Konkan area of Bombay, big landlords store their paddy in rooms, and rectangular compartments are made by nailing wooden planks together.

Storage of Paddy for Seeds. The cultivator exercises much care in the storage of seed paddy, as he does in the case of wheat and other cereals. In West Bengal, paddy for seed is stored either in straw packages or in earthen vessels securely sealed with mud. Straw packages are also employed for the purpose in Assam, Bihar, Orissa and Madhya Pradesh. Paddy reserved for seed is also invariably conserved in earthen pots or jars. The cultivator usually takes particular care to dry thoroughly his seed paddy in the sun before it is stored. Where the source of seed supply is the village merchant, the quality, purity and germinating capacity of the seed thus obtained often leave much to be desired, as the village merchant takes no special steps to keep the grain in the best possible condition.

RICE STORAGE

In the Markets. Since about half of the marketable surplus of the rice crop is moved to the market during the first four months of the crop year, the question of storage at this place is more important. In practically all the markets, both in producing and consuming centres, merchants possess permanent storage accommodation in the form of godowns or warehouses which are usually built of masonry and, in a number of instances, have cement floors or are paved with flagstones. Before storing the produce in these godowns, some kind of covering such as bamboo mats is usually spread on the floor, especially if the latter is of beaten earth (*kutcha*). This precaution is generally considered necessary to minimise damage or loss caused by dampness. In certain wholesale markets of Madhya Pradesh, merchants who are unable to find sufficient accommodation in their places of business in the market place often use rooms or other parts of their residence for storing goods. While paddy is stored both in bulk and in bags in nearly every state, the husked product or rice is generally kept in bags. The main exceptions to this rule occur in three States. In the Punjab, for example, where the produce is comparatively small, bulk storage is rare, bags being used both for paddy and rice. In West Bengal, rice is conserved not only in bags but in bulk also, while in Madhya Pradesh merchants prefer bulk storage for rice.

At the Mills. Storage accommodation in the average rice mill consists of godowns with cemented floors and masonry or corrugated iron roofing. While paddy is kept both in bulk and in bags, milled rice is invariably packed and tored in bags. Stocks of rice are rarely kept for any length of time, the goods being generally despatched as soon as milled.

At The Ports. Both paddy and rice are usually stored in bags, although comparatively a little paddy is handled on the dock sides of the various ports. As a general rule, imported paddy and rice are rarely kept for any length of time in the Port Authority warehouses, owing to the relatively high scale of charges.

STORAGE COST

In the Villages. It is impossible to give an accurate estimate of the costs of conservation on the holding or in the villages, as in the majority of instances, the produce is stored in home-made receptacles, the value of which is not easy to assess owing to the fact that the material used in their construction is usually some by-product of the field, and the labour expended thereon is that of the cultivator or his family.

In the Markets. Storage costs in the markets have been found to be highly variable in different parts, as the storage costs depend primarily upon the three main factors of warehouse or godown rent, handling charges (filling or stacking and removal) and interest. The first two items hinge on the type of storage accommodation available, and the last on the amount of capital invested, money market conditions and duration of storage. These are liable to vary from place to place, and in different seasons.

The storage costs naturally display great variations between the different markets, depending upon the type of storage, period of storage and the importance of the market. In Madras, an important rice-producing State, the cost of storing paddy at Ellore is presently about 5.88 pies per maund per month in *gadi* and in case of *pukka* godowns, it is about 20.24 pies per maund per month. Table 103 shows the various items included in the storage charges of rice and paddy.

TABLE 103. ANALYSIS OF STORAGE CHARGES IN MADRAS STATE (PIES PER MAUND PER MONTH)

Market	Type of storage	Rent	Handling	Depreciation on bags	Interest	Total
Ellore	*Gadi*	1.0	0.8	—	4.08	5.88
Ellore	*Dhanyappa Kottu*	1.2	0.8	—	4.08	6.08
Madras	*Pukka* godown	9.0	3.0	2.0	6.24	20.24

In Orissa, the cost of storage on an average is reported to be ten pies to one anna per maund per month, for paddy and rice, respectively. These include rent, handling charges, interest on capital, cost of container, etc. In West Bengal, the cost of storage of paddy in Burdwan is said to be one anna per maund, both for paddy and rice.

At the Mills. The question of storage charges in the mills does not arise, as the storage accommodation is a part and parcel of the mill premises. Where

outside accommodation is hired owing to the mill godowns being full, rents vary with locality.

LOSS IN STORAGE

Paddy suffers less damage than rice, although both paddy and rice, besides undergoing loss in weight due to driage, are susceptible to losses in storage on account of floor-dampness, weevil infestation and vermin attack. Paddy (fit for storage) may lose one to three per cent. in weight during storage in the hot months due to driage, while rice may lose ½ to 1½ per cent., when carried to two to four months under comparatively dry conditions. There is a subsequent gain in weight in the rainy season, but in the case of paddy by the time the monsoon arrives, the bulk of the marketable surplus gets converted into rice.

Dampness, seepage through the floor, especially when it is a *kutcha* one, adversely affects the quality of the lower portion of the heap if stored in bulk, and of the lower bags of the stack, if stored in bags. In order to avoid this damage, some sort of material such as straw-matting or wooden sleepers are often laid on the floor.

The extent of loss due to weevil attack depends on the atmospheric conditions at the place of storage, the length of storage and the method and conditions of storage. The quantitative estimate of losses by weevil, dampness and vermin attack, totals 3,17,000 tons of rice annually, or slightly more than one per cent. Of this loss, about 48 per cent. is understood to take place in paddy storage and the remainder in rice. On the basis of the storage loss of about one per cent. and based on the average production for the quinquennium period ending 1954-55, the total loss is placed at 2,31,400 tons. Besides storage losses, losses also occur during handling and transportation. The Rice Bulletin issued by the F.A.O. (1949) says: "According to competent authorities, the annual preventible losses of rice (which occur during handling, transportation and storage) exceed the total quantity that flowed into international trade in 1948."

This means that the losses total up over three million tons, or over two per cent. of production.

EFFECTS OF STORAGE ON QUALITY

Paddy keeps almost indefinitely provided the grain has been properly dried and stored in a dry place. When subsequently hulled for use, such produce retains its original colour and when cooked, has the characteristic flavour of the variety.

As regards rice, highly variable results are obtained with different qualities. For instance, hand-pounded rice or rice which has been very lightly milled, undergoes rapid deterioration if stored for any length of time. As far as can be ascertained, the question of the rate of deterioration in relation to different varieties under varying conditions has not been studied in detail.

Parboiled rice reacts to storage somewhat differently from raw rice. The former has been observed to discolour and become yellowish, possibly due to the greater moisture-content in the grain when, as may frequently happen, the paddy has been insufficiently dried after the steeping process. Parboiled rice, however, has an advantage over raw rice as regards storage, in that it is less affected by weevil attack. The comparative immunity of parboiled rice would seem to be

largely due to the toughness imparted to the grain by the parboiling treatment. Kernels of parboiled rice acquire a hard, smooth, glossy surface which apparently affords a poor grip for the mandibles of insect pests.

So far as improvement in cooking quality of stored or matured rice is concerned, experiments undertaken at the Indian Institute of Science, Bangalore and at the Rice Research Station, Coimbatore, have confirmed the ordinary domestic experience of grains retaining their individuality when matured rice is cooked.

New rice tends to cook rapidly into a meshy glutinous consistency. Further, stored or matured rice absorbs more water than unstored rice and swells or elongates to a great extent.

The optimum length of storage is difficult or almost impossible to determine with any degree of accuracy and if ascertainable, the value would probably be of doubtful practicability owing to the diversities in consumer preferences, and the variability of the time and method adopted by consumers to cook the cereal.

The trade, however, has a rough and ready classification for stored rice. For instance, in Uttar Pradesh, where rice is stored in the form of the husked produce and not paddy, three years are supposed to be an optimum period of storage for fine rice, and one to 1½ years for medium and coarse types. In the Punjab, also noted for its fine and scented rices, two to three years must elapse before these qualities are considered to be at their best. With regard to the ordinary run of cheap or medium rate rices, these are not, for preference, consumed until about three months have elapsed from the time of harvesting. However, the greater the intervening period, the better they are.

STORAGE ACCOMMODATION

Stocks and Carry-over. The position in regard to the recording of stocks of rice and paddy, normally speaking, is extremely unsatisfactory. In the case of wheat, the trade is, by comparison, well-organized and reasonably accurate records of stocks are maintained at a number of important centres, especially by some of the associations handling this type of business, who keep a register of supplies held in *khattis* (underground pits). No such arrangements exist in regard to rice. Consequently, any estimation of carry-overs—difficult enough to make in respect of commodities for which some data are available—becomes virtually impossible with rice.

None of the smaller mills, operating, say, only one or two hullers, keeps any records whatsoever, while the majority of the larger mills do not ordinarily maintain detailed figures. The total quantity of paddy or rice for which no reliable figures of mill-stock can normally be obtained is so insignificant that no valid conclusions can be arrived at for the country as a whole. Such estimates, as are made by the trade periodically, are largely founded on intelligent guess work based on long experience of market conditions.

Estimates of stock, as ascertained from private trade sources in different parts of the country, reveal that rice stocks rise in the immediate post-harvest months, and throughout the height of the milling season which begins to wane after May.

As Table 104, based on the three years' survey made before the war, shows, stocks are normally the greatest between March and June, and begin to

diminish thereafter, reaching their lowest levels in December and January, at a time when the new crop arrivals have not yet made their appearance felt in the market.

TABLE 104. MONTHLY STOCKS OF RICE OF REPRESENTATIVE CENTRES IN FOUR STATES EXPRESSED AS A PERCENTAGE OF THE ANNUAL TOTAL

Months	Uttar Pradesh Banaras	Punjab Amritsar	Madhya Pradesh Raipur	Bombay Bombay
January	8	8	9	5
February	9	9	11	8
March	10	10	11	9
April	11	9	12	11
May	10	10	10	12
June	10	8	9	12
July	10	7	7	8
August	7	7	4	10
September	7	7	6	7
October	6	7	7	7
November	6	9	7	10
December	6	9	7	1
Total	100	100	100	100

With regard to the other areas, enquiries showed that in West Bengal and Bihar, stocks of rice were normally the greatest in February and March, and continued to maintain a high level until June and July, when they began to diminish reaching the bottom from November to December. Stocks of rice in Uttar Pradesh and the Punjab were also reported to be the highest in February and March, the period of low supply extending from July to September. In Madras, rice stocks did not exhibit any marked seasonality although April, May and June appeared to have relatively greater supplies than any other period of the year, when stocks are maintained at a fairly constant level.

The position with regard to stocks and carry-overs and actual quantities of stocks maintained in different areas from month to month, however, underwent considerable change during the period of War and controls. This became dependent on the procurement drive and the distribution arrangements, the stocks of which, of course, varied from state to state, and even from year to year within the same state. Since decontrol, no further studies have been undertaken about the stocks and carry-overs, and, as such, no correct assessment can be made.

STORAGE AND INSPECTION ORGANIZATIONS

Realising the importance of storage and the need for cutting down losses especially in periods of shortage, and keeping in mind the procurement activities of the State Governments and the responsibilities of the Centre regarding food, the proposal for reserve stocks and storage needs for imported foodgrains, the Government of India has established a Storage Directorate in the Ministry of Food and Agriculture with technically qualified staff. One of its important duties is to advise on technical matters concerning storage.

CHAPTER 29

HANDLING AND TRANSPORTATION

The handling involved in connection with loading into carts or on pack animals, unloading and weighing or measuring the produce when sold directly off the threshing floor or when taken from the village to the market, is generally done by the cultivator and his family assisted by the buyer and hired labour when necessary. Paddy is generally handled in bulk. In Madras, it is also handled and packed in straw containers known as *muras*. Hand-pounded rice which largely originates in villages, is handled in bags as well as in bulk.

After the produce reaches the market, the subsequent handling of both paddy and rice for movement by road, rail and water is generally in bags called 'gunnies' or 'gunny bags.' The types of bags commonly used are heavy C.D.W. (double warp) and B. Twill. Fillings of one maund twenty four seers (131 lb.) to one maund thirty seers (144 lb.) are common for paddy, while in the case of rice there is a wide range of fillings from about two maunds (164 lb.) to two maunds 30 seers (226 lb.), and in exceptional instances even a little more. The operations involved in the handling of the produce, such as loading and unloading, filling into bags, stitching bags, stacking bags, etc., are attended to by hired labour called *palledar* or *hamals*.

At the railhead, both paddy and rice are handled in bags except in Assam where paddy is transported in bulk and bagged at the destination. The handling of the bags from the railway shed to the wagons, and vice versa, is ordinarily done by labourers employed by the railway, but in the case of transport in bulk and full wagon-load consignments, loading of wagons at source and unloading at destination are done by the labour provided by consignors and consignees respectively.

The handling at the riverhead is similar to that at the railhead, the produce being generally packed in bags. In Assam, however, paddy is conveyed in bulk in country craft, though the produce is bagged at the time of off-loading. At the ports, the loading and discharging of sea-going vessels is done by cranes at all big ports, but at several minor ports, ships have to lie far out off-shore and the produce is transported in bags from the shore to the lighters. Both paddy and rice are generally handled in bags except in the case of country sailing craft when paddy is sometimes handled in bulk. Imported rice in bags is often transhipped directly overside from the steamer to boats either in the dock or out in the stream.

The cost of handling varies in different cases and in different areas, depending on the operations involved and charges for labour. The cost of handling in villages and in some markets may range from one anna to one and a half annas per maund while at ports and larger markets, the cost may work out from one to two annas per maund.

TRANSPORTATION

The movement of paddy and rice from the producing tracts to the assembling centres in the interior takes place mostly by road, bullock carts and pack animals.

Rail and river transport are more important for subsequent movement, but road transport by motor lorries also takes a substantial share.

COST OF CONVEYANCE

By Road. The cost of transport by road varies enormously. Long distance hire is relatively cheaper than short hauls, and rates are frequently doubled during the monsoon. Sometimes, higher charges may be paid in kind as in the Punjab, where 1/32 part of the produce carried is handed over to the owner of the conveyance for a carry of about 4 miles. The present costs of conveyance by carts in Madras are generally about 4 pies per maund per mile on metalled road and 5 pies per maund per mile on unmetalled road for long distances of over 30 miles, the charges for distances shorter than 30 miles being 8 pies per maund per mile. The charges by motor truck, are reported to be 4 pies per maund per mile. In Orissa, the present cart-rate varies from 5 pies to 7.2 pies per maund per mile, though the rate sanctioned by the Government is 5 pies per maund per mile. The cost of conveyance by truck is estimated at 3 pies per maund per mile. At present, 20 per cent. of the rice and paddy is being transported by this mode of conveyance, as against 5 per cent. in the pre-war period, due to the increasing convenience by this mode of transport. In Mysore, the present cost of transport by lorries is reported to be 2 pies per maund per mile. In West Bengal, the present cost of transport by cart ranges between 6 pies per maund per mile in the 24-Parganas and 2 annas per maund per mile in Malda, Burdwan and West Dinajpur districts. In Calcutta itself, the cost is 24 pies per maund per mile while the pre-War cost was about 3 pies per maund per mile. Thus the rise in cost is about 700 per cent. over the pre-War level. In Bombay, the rates of lorry hire are fixed and approved for payment by the District Magistrates. These range from a minimum of 4 annas 6 pies per ton-mile in Bijapur to 8 annas per ton-mile in Kaira.

By Rail. The Railways carry a considerable quantity of rice and paddy. According to the figures published, the Indian Railways carried 6,29,800 tons of paddy and 21,20,600 tons of rice in 1953-54, and 25,03,100 tons of rice and 7,48,200 tons of paddy in 1954-55, originating on the home-lines within the railway zones. The principle governing the fixation of freight rates for different commodities are summed up in the 'Monograph on Indian Railways Goods Rating Structure' issued by the Railway Board. Freight rates for rice and paddy are quoted by the Railways in accordance with the schedule or classification laid down by the Railway Board for various commodities. Rice and paddy are indexed to the main head 'Grains' and 'Pulses' and are charged at the following basis.

TABLE 105. BASIS OF TELESCOPIC CLASS RATES (PIES PER MAUND PER MILE)

For the first 300 miles	Plus for next 300 miles	Plus distances beyond	Maximum rate per maund
·54	·45	·34	Rs. 3·19

The rates* of wagon-load scale are ·38/300 miles, plus ·26/300 miles, plus ·17 for distances beyond the maximum not exceeding Rs. 1·81 p.m.

The Railways also offer special reduced rates. A station-to-station rate is a special rate per maund for the total distance between two specific points. A special rate may be in operation between two stations on the same Railway, between two stations on different Railways, between a junction and a station, or between two junctions. These rates are inclusive of terminal short distance charges, tolls, etc.

By Internal Waterways. Since rice is largely the product of low-lying areas intersected by rivers and canals, transportation by water is a common feature in West Bengal, Assam, Bihar, Orissa, Madras and Kerala. A considerable amount of paddy and rice is also carried on by some of the rivers of Uttar Pradesh, notably the Ganges. The Ganges in its lower reaches links up Bihar with West Bengal, while rivers such as Mahanadi and Brahamani in Orissa play an important part in the distribution of paddy and rice. Canals and other artificial waterways capable of navigation either seasonally or throughout the year also carry much traffic in paddy and rice, as for example in Madras and Kerala.

It is unfortunately extremely difficult to precisely ascertain how much of paddy and rice is carried by the waterways in India, but judging from the extent of this traffic in Madras, the probable total traffic of rice and paddy by internal waterways can hardly fall short of one million tons, and may indeed be much greater. The cost of transport by water, particularly by country boats, is, on the average, lower than that by road, as freights by country boats are always open to negotiation as in the case with the lorry and cart transport, and on that account vary considerably. Only organized transport agencies such as river steamer companies quote fixed rates.

Besides the traffic in internal waterways, there is a considerable coastal traffic in paddy and rice in the fair season which lasts from the end of September to May. A large proportion of this traffic is between one maritime state to another, but a good deal of trade also goes on between ports in the same state. Shipments are recorded only at the important ports having custom houses, but the paddy and rice carried between villages and small towns on the sea coast or up inlets or creeks are not registered. The foreign shipment trade, comprising mostly of imports in recent years and to some extent exports, is almost wholly carried by steamers.

An idea of the comparative cost of transport by rail, road (lorry) and the boat, can be had from the following example from Kerala.

The railway freight charges per ton (27 mds.) by goods train from Quilon to Trivandrum, a distance of 42 miles is Rs. 4-10-0. The charges for road transport (lorry) for one ton between the same two places, 44 miles by road route, are Rs. 16-8-0. The charges for back water transport (in canoes) for one ton between the same two places, 40 miles, are Rs. 5. Thus it will appear that the cost is the same by rail and water transport.

* These rates are exclusive of terminals, transhipment and other extra charges, which should be added.

CHAPTER 30

DISTRIBUTION

Of the total marketable surplus of rice, 89 per cent. was estimated to enter the normal channels of wholesale trade in the pre-war years, the remaining 11 per cent. being distributed directly in the villages and periodical markets by growers and petty traders such as village merchants, professional dehuskers, etc. Supplies reaching the wholesale assembling markets consist not only of paddy, the form in which the crop is harvested, but also of hand-pounded rice. The former, with the exception of relatively small quantities used for making parched products, is converted into rice by power-driven rice mills. Of the total quantity milled, it was reckoned that about four per cent. comprised rice milled on hire at milling centres by growers, village merchants, etc., to be marketed later. The remaining quantity was milled on hire by wholesale merchants and by rice mills on their own account. The relative shares handled by these two agencies vary considerably in different states. Rough pre-war estimates, however, put the proportion of rice milled on hire by wholesale merchants throughout India at 40 to 45 per cent., leaving 55 to 60 per cent. as representing the rice milling industries' output on its own account. The areas in which the mills are the most important buyers of paddy and where milling on hire by traders is comparatively less are West Bengal, Madras, Bombay, Mysore and Kerala. With the removal of ban on movement, distribution, etc., after the decontrol in 1954, the position has, more or less, returned to normal.

AGENCIES AND METHODS

A brief description of the part played by different agencies in the distributive process is given below.

Cultivators, landlords, village merchants, itinerant dealers and professional dehuskers who all take a significant share in the assembling of the crop do not play any important part in the distribution of rice. Only about 11 per cent. of the marketable surplus is distributed by these agencies by direct sales to consumers or retailers in the villages and periodical markets.

Wholesale merchants and commission agents are the most important agencies for the distribution of rice, and it would probably be true to say that roughly 80 per cent. of the total marketable surplus passes through their hands. They stock paddy, have it milled on hire, and distribute rice and its by-products. Rice mills purchasing paddy and milling on their account may distribute the rice directly through their branches or through commission agents, the latter practice being more common.

The extent of participation in the marketing of rice crop by co-operative organizations generally does not extend beyond the assembling stages. A few societies, however, have attained some measure of success in wholesale distribution as well.

Presently, the imports of rice into India are on Government account, but in the pre-control period, private firms participated in the trade. Some of them, particularly from Calcutta, also interested themselves in a relatively small export trade. Presently, private firms are also participating in the export trade under a system of export licence quota of the Government. During the period of war and controls, the Government became the main, if not the sole distribution agency in several states.

FINANCE FOR WHOLESALE DISTRIBUTION

The distribution of rice from the assembling to the terminal markets or centres of consumption is mainly financed by wholesale merchants or commission agents. The rate of interest on such advances depends entirely on the credit and the business relations existing between the parties concerned.

The actual provision of funds is effected through Shroffs (indigenous bankers) and the scheduled joint-stock banks both working along similar general lines, including making advances against pledged stocks, discounted *hundis* or Drafts and giving short or long-term loans. The Shroffs generally have the advantage of being in closer touch with their clients, and having better acquaintance with their personal, domestic and business affairs. They are, therefore, often prepared to undertake risks which banks do not. They, therefore, remained the main source of financing the distribution. Co-operative consumers' organizations, of late, are beginning to have some share in the financing and distribution of rice. The state and district co-operative urban banks, particularly in Madras, have had some share in financing the distribution of rice through, what are known as multi-purpose societies.

COST OF WHOLESALE DISTRIBUTION

The cost of wholesale distribution depends upon the extent of movement and the agencies involved. When paddy and rice are directly distributed in the villages and in the periodical markets by growers, landlords and others, the cost of distribution is very small. When the merchants and mills distribute rice, the costs in the case of local sales include expenses on handling and transport, market charges, commission and brokerage, etc. But, when goods are consigned to distant consuming centres, the distribution costs include expenses on railway freight or boat hire, etc., and expenses at destination. Freight is generally the biggest single item in the distribution costs. The few examples of the cost of distribution given below reveal that railway freight accounts for 75 per cent. of the total distribution costs, the remaining 25 per cent. being absorbed on items like handling, packing, cleaning, commission to various functionaries, etc.

TRADE ASSOCIATIONS

The majority of the rice trade associations are small bodies of purely local influence, and the only ones of any size and importance are the Calcutta Rice Merchants' Association, the Calcutta Grain, Rice and Oil Mills Association and the Bombay Rice Merchants' Association. The three Associations work on a no-profit basis, and have the promotion and protection of the trade interests and arbitration

TABLE 106. COST OF DISTRIBUTION OF RICE—AMRITSAR TO CALCUTTA

Items	Percentage of cost per 40 bags
Value of new gunnies (double-bagging) less half the price of the used bags realised by sale at destination	6.2
Handling and carriage to station @ Rs. 0-1-3 per bag	1.9
Railway freight	68.8
Clearing agent's fee at Howrah Station	0.8
Cartage from Railway Station to buyer's godown @ 2 annas per bag	3.1
Selling commission @ 1½ per cent.	6.5
Selling brokerage @ 12 annas per cent.	3.3
Godown rent and miscellaneous expenses	1.9
Muddat (discount) @ 2 per cent.	7.5
Net Total	100.0

TABLE 107. COST OF DISTRIBUTION OF RICE—BOLPUR TO DELHI

Items	Percentage of cost per maund
Value of gunny bag (single-bagging) less realisation from the sale of used bags	3.2
Filling and sewing	1 6
Cartage to station	4 9
Station expenses	1.6
Bolpur commission agent's fee	3.2
Railway freight to Delhi	69.4
Terminal tax at Delhi	3.2
Handling and cartage to godown at Delhi	3.2
Seller's commission at Delhi	9.7
Net Total	100.0

TABLE 108. COST OF DISTRIBUTION OF RICE—RAIPUR TO HARDA

Items		Percentage of cost per 31 bags
Charges at origin (Raipur)—		
Value of gunny bags	..	9·1
Arhat (commission) @ Re. 1 per cent.	..	3·2
Dharmada (charity) @ 1 anna per cent.	..	0·2
Postage (*chiti*)	..	0·3
Handling and cartage to Raipur Railway Station @ 3 annas per bag inclusive of terminal tax	..	6·8
Miscellaneous (*gowshala*) or cattle home	..	0·2
Percentage of total expenses at origin	..	19·8
Discount on *hundi* @ Re. 0-4-6	..	1·0
Expenses at destination (Harda)		
Railway freight	..	78·4
Terminal tax 6 pies per md.	..	3·0
Cartage from station to godown	..	2·3
Percentage of total expenses at destination	..	104·5
Less value of used gunny	..	4·5
Net Total	..	100·0

TABLE 109. COST OF DISTRIBUTION OF RICE—BEZWADA* TO GADAG

Item		Percentage of cost per bag of 246 lb.
Charges at origin (Bezwada)*		
Value of gunny bags	..	8·2
Arhat (commission)	..	4·1
Dharmada		—
Postage		—
Handling and sewing (*hamali* and *silai*) of bags	..	2·0
Cartage	..	2·0
Miscellaneous (station charges including *hundekarai*, forwarding agent or station broker)	..	1·0
Percentage of total expenses at origin	..	17·3
Expenses at destination (Gadag)		
Railway freight		79·6
Terminal tax	..	3·1
Cartage from station to godown	..	3·1
Station expenses	..	1·0
Percentage of total expenses at destination	..	104·1
Less value of used gunny	..	4·1
Net Total	..	100·0

* Vijayawada

and settlement of disputes as their general objects. In addition to purely trade associations, there are also a few associations of rice mills. The objects for which these bodies have been established are much the same as those of the trade associations but their more immediate problems concern such matters as factory legislation, adequate supply of paddy, railway freight rates, etc.

AGENCIES AND METHODS

Retail Distribution. In the rural areas, the village *banya* (merchant) is the most important agency for the retail distribution of rice as also of other articles of daily consumption. In the rice-producing areas, his source of supply is mainly the cultivator, who may dispose of his produce for cash or part with it in settlement of previous loans. The barter system is also not uncommon, paddy and rice may be exchanged for groceries. The cultivators themselves also play some part in retail distribution. Besides selling in the villages to individual consumers, they attend periodical markets held at village centres or nearby towns, and retail small quantities. Professional dehuskers also participate in the retail trade in much the same way as the growers. In urban centres, the retail distribution of rice is carried on by retailers who deal in several other articles of food, such as flour, pulses, sugar, spices, etc.

RETAIL MARGINS

The difference between the price paid by a retailer when acquiring his stock-in-trade and that realised by him from his customer constitutes his retail margin. This includes the expenditure incurred in transporting the goods to the shop from his source of supply and handling and preparing the produce for sale, rent, rates and taxes and profits. These items (excluding profit) in the aggregate amounted to something between 6 pies and 2 annas per maund in the pre-war period. Taking the present high costs, these could be easily three times that amount.

A somewhat remarkable fact about the retail margins in the rice trade (the retailing of paddy is so small as to be negligible) is their extreme variability. This is in keeping with the price of this grain, which, it may be remembered, has a unique range of something like 700 per cent. Broadly speaking, it has been observed that costly rice carries relatively large margins, while cheap rice having a rapid turnover is sold on a highly competitive basis with smaller margins. The seeming anomaly is readily explained by the fact that the confusing multiplicity of nomenclature and the outward similarity of a large number of varieties in the retail trade, for the most part, provide an opportunity of mixing and adulteration under the pretext of rice being 'blended' to suit local tastes. Thus a variety of rice alleged to belong to a certain trade description may actually be retailed at a price lower than quoted in the wholesale market for the same description. Another explanation for the wide variability of the retail margins lies in the process of bargaining which accompanies almost every transaction. Retail prices are ordinarily never marked on the article offered for sale, and the first price asked by the retailer is generally put forward more as the basis for negotiation and higgling than as a serious quotation.

PRICE-SPREAD FROM PRODUCER TO CONSUMER

The producer's share in the price paid by the consumer is more variable and difficult to assess in the case of the rice crop than in respect of most other primary

TABLE 110. ANALYSIS OF PRICE-SPREAD BETWEEN PRODUCER AND CONSUMER

Price Factors	Saharanpur (U.P.) to Kanpur Basmati rice (parboiled)	Raipur to Nagpur Hansa rice: Cultivator selling paddy to merchant and the latter hulling on hire	Raipur to Nagpur Hansa rice: Cultivator milling his paddy on hire and selling rice	Cuttack Local distribution Panchkulia rice (mixture)	Bolpur (Bengal) to Delhi Dhundhkalma rice (boiled)	Tadepallegudam (W. Godavari) to Madras Akhulu rice	Warangal (Andhra Pradesh) to Hyderabad Khichidi rice	Kalyan (Bombay State) to Bombay Calamba rice
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Cultivator's price* ..	66.9	57.6	—	77.8	57.8	63.2	69.5	75.7
Expenses up to completion of milling ..	9.7	5.4	—	8.6	9.5	9.1	8.9	7.1
Profit margin on hulling ..	2.7	7.9	—	4.3	7.7	3.3	2.2	3.4
Expenses to f.o.r. including bagging cartage and market charges (if any) ..	1.6	4.1	—	(Disposed of locally)	2.5	4.4	2.9	2.4
Freight ..	6.2	7.9	—	-do-	13.2	10.0	4.8	1.5
Expenses at destination ..	1.6	3.5	—	-do-	3.1	1.7	0.6	2.3
Wholesaler's margin ..	2.3	7.3	—	2.9	2.5	3.3	2.0	3.4
Retail margin ..	9.0	6.3	—	6.4	3.7	5.0	9.1	4.2
Total value realised of the salable products resulting from conversion of paddy ..	100	100	100**	100	100	100	100	100

* Disregarding any deduction by way of interest on loans; ** Of this, the cultivator's share was 68

products, on account of the crop being marketed under a great diversity of conditions.

For instance, the crop may be put in the market in the form of paddy, or hand-pounded or machine-milled rice, the hand-pounded rice having been converted in the grower's house or by the professional dehuskers. Again, some of the machine-milled rice may be milled on hire by the various assembling and distributing agencies including cultivators while in other cases, the processing may be on account of the rice mills as the owner of the produce. Further, a certain proportion of the crop is marketed in the form of raw rice, and some proportion as parboiled. The producer obtains different returns, depending on the channels through which the produce eventually finds its way to the consumer. It is impossible to take into precise reckoning all these variable conditions in endeavouring to determine the share of the grower in the consumer's price. A few illustrations of the price-spread are given in Table 110.

It will be readily seen from Table 110 that in cases involving transportation by rail to consuming centres, the share of the producer, provided he brought his produce to the assembling centres in his own cart, varies by 57.6 per cent. to 75.7 per cent. of the total value of the salable products yielded by his paddy. It is obvious that the share of the producer depends, amongst other things, on the incidence of railway freight charges; the higher these are, the lower the net returns of the producer. The examples given above are representative of long, intermediate and short hauls. On these basis, the share of the producer works out to 66 per cent. of the rupee paid by the consumer.

When rice is distributed locally for milling or in the vicinity, the producer's share, on an average, comes roughly to about 70 per cent.

Reverting to the assembling stage, it was estimated that only 13.6 per cent. of marketable surplus was actually brought to the market by the growers themselves. The figure of 71 or 72 per cent. as representing the producer's returns was based on the assumption that the grower himself was responsible for assembling his entire marketable surplus. This is far from being the case, as the cultivator is estimated to dispose of something over 75 per cent. of the surplus to the various assembling middle men. It must also be borne in mind that goods often change hands more than once before reaching the market, and their eventual destination. As a result, the producer's share of the consumer's price would diminish with each transaction, especially when both the parties were the principals in which case there would, in theory, be a difference between the buying and selling prices. Taking all these factors into consideration, and also inasmuch as the grower has to pay a considerable proportion of his returns towards interest charged on loans, borrowed for raising the rice crop, etc., the net share of the producer is ultimately placed at about 50 to 60 per cent. of the rupee paid by the consumer, which is very low indeed.

MANUFACTURING AND DISTRIBUTION OF RICE PRODUCTS

The three principal rice products of any commercial importance in India are the parched rice (*murmura*), beaten rice (*chura*) and parched paddy (*kheel*). Although the proportion is relatively small, the quantity of rice processed into these products is fairly considerable, and provides employment for a large community known generally as *Bharbhunjas* as a cottage industry.

The total quantity of paddy (or rice) used in the manufacture of parched rice, beaten rice and parched paddy does not yield an equivalent quantity of products. Certain losses inevitably take place as, for example, in the natural moisture of the grain which is driven off by the parching process, a treatment in which great heat is applied. Some of the grains also fail to expand sufficiently, and are winnowed out when the product is finally being dressed before being put up for disposal. Enquiries made at parching establishments in various parts of the country provide a very fair estimate regarding the actual recovery of parched products and beaten rice from a given quantity of raw material. The proportions naturally vary according to the type of the rice used, the treatment given and the amount of winnowing and dressing the finished product is subjected to. When parched rice is being made direct from parboiled rice (not from paddy), an outturn of between 85 to 90 per cent. may be normally expected. From areas as far apart as West Bengal, Delhi and Baroda, the percentage recovery is reported to be 87.5 per cent. When parched rice is prepared from paddy, the net recovery based on conditions in the major states, averaged, in round terms, to 60 per cent. This tallied closely with the net recovery of parched rice prepared directly from parboiled rice, the outturn of the former calculated on the equivalent of paddy working out to be roughly 59 per cent. Variations in the percentage recovery of parched rice from paddy range from 47.51 per cent. in Uttar Pradesh to 73.7 per cent. in Bombay. In the majority of instances, 55 and 61 per cent. were the normal limits.

The average recovery of parched paddy from paddy was 61 per cent. with a range of 50 per cent . in Uttar Pradesh to 67.5 per cent. in Bihar and Orissa.

The beaten rice showed an average outturn of 64.5 per cent., the outturn being the least in Kerala where it was given as 56.3 per cent. and the greatest in Baroda, where the proportion was 66.7 per cent.

PRODUCTION

The quantity of rice products manufactured in the various states differs considerably and, to a large extent, reflects the demand, the character of which is variable and fairly localised. No data are available to show the volume of trade in parched rice, parched paddy and beaten rice, but enquiries made reveal that while this is not large—probably not more than ten per cent. of the total production —beaten rice occupies a more important position from the marketing viewpoint than either of the other two kinds of preparations. This is due to the ability of

beaten rice to be kept for several months without deterioration. The quantity of parched paddy manufactured is much smaller than that of parched rice, and the beaten rice and its consumption exhibits a distinct seasonality in the late autumn in North India generally, and in West Bengal particularly owing to religious festivals which occur during October and November.

COSTS AND METHODS OF MANUFACTURE

Parched rice is generally made from parboiled rice. The method adopted for parching is generally to pour rice over sand in an open iron pan or earthen vessel, kept over a fire and rapidly stirring it with a long metal ladle. As soon as the rice begins to crackle and swell, the contents of the pan are transferred to a sieve and the sand separated. The insufficiently expanded kernels are separated by winnowing and ground into flour by the hand-*chakki*. This is known as *sattu*. A product similar to parched rice, known as *murhi* in Bihar and Orissa, is prepared from paddy by a different process. Paddy is soaked in water for two or three days and then boiled for one to two hours which is followed up by drying (in the sun), dehusking (by pestle and mortar), salting, frying and finally parching in the usual way.

Parched paddy is prepared by first drying the paddy in the sun for 12 hours, filling the dried paddy into large earthen jars, pouring hot water into the jars, emptying out the water after two or three minutes and keeping the jars in an inverted position throughout the night exposing moist paddy next morning to the sun for a short period and while still moist, kneading and parching it as in the case of parched rice. After parching has been completed, the sand and the grains are separated through a sieve and the produce subsequently winnowed to remove the husk. The resultant products are: (*i*) *Kheel* (burst soft white kernels), (*ii*) *thuddi* (unburst hard parched kernels) and (*iii*) husk. *Thuddis* are manufactured into an inferior quality *murmura*.

For the preparation of beaten rice, paddy is steeped in water for two or three days to soften the kernel and then boiled for a few minutes. When the water in which the grain has been boiled has cooled, it is drained off, and the paddy kept over a strong fire in shallow earthenware vessels or iron pans until the husk bursts open. The next operation consists of pounding the grain, generally by means of a wooden pestle. This flattens the rice kernels and removes the husk. The latter is finally separated by winnowing in the usual way in a tray (*suba*).

PROCESSING COSTS

The processing cost varies according to the wages paid, the value of the fuel used, the rent of the premises and other incidental expenses.

MANUFACTURERS' RETURNS

The different varieties of paddy (and rice) used and the varying items of manufacturing costs are jointly responsible for a fairly wide divergence in the returns earned by markets of parched products and beaten rice.

In West Bengal, the average price which the wholesalers pay at present to the manufacturers are Rs. 30 to Rs. 35 per maund of *chura* and Rs. 30 for *muri* and *khoi*. The manufacturers' returns amount to Rs. 2 to Rs. 3 for *chira* and Rs. 2 to

4 for *muri* and *khoi*. The manufacturers' margin may be roughly estimated at between 10 and 15 per cent.

In Orissa, where each manufacturer does the business on a small scale, and himself engages in the direct sale of his product to the consumer, and thus taking upon himself the role of both manufacturer and retailer, the manufacturers' margin is generally much larger including as it does the profits which are usually made by the wholesaler and the retailer. Enquiries in Orissa indicate that the manufacturer's cost of production is Rs. 21-6-0 per maund of *mudhi*, Rs. 20-3-0 per maund of *chuda* and Rs. 18-4-0 per maund of *khali*, while the rate of retail prices being Rs. 32-8-0, Rs. 25 and Rs. 35 per maund, respectively. The manufacturers' returns are thus over 50 per cent. in the case of *mudhi*, about 25 per cent. in the case of *chuda*, and about 29 per cent. in the case of *khali*. As the small manufacturer does not ordinarily pay for labour which is supplied by his family, his returns from this manufacturing activity may be considered even higher. Manufacturing of rice products is, therefore, a very paying and profitable occupation for these small manufacturer retailers.

RELATION BETWEEN THE PRICES OF PADDY AND RICE AND THEIR RESPECTIVE PRODUCTS

No records of the prices of the various rice products are maintained officially, nor are quotations available from those engaged in the manufacturing and distributing trades. In a few important centres such as Calcutta, Agra or Kanpur where a certain number of wholesale merchants handle rice products on an appreciable scale, it is possible to obtain some price data, but these too are not available for a sufficiently long and continuous period. Unfortunately, such data are of little significance owing to the total absence of standard qualities and the wide range of values which exist between different grades, particularly in respect of beaten rice.

DISTRIBUTION

Wholesale. The term 'wholesale' as used in this paragraph must be interpreted in a relative sense. The nature of the trade in rice products is such that really large quantities are not involved in a single transaction. As a rough, general guide, it may be taken that ten bags, or about 15 maunds is probably the smallest quantity that may be regarded as a wholesale lot. Parcels up to 100 or 150 bags at a time may be consigned from producing areas to consuming ones, but the volume of trade handled in lots of this size is very small indeed.

The wholesale distribution of rice products is not a very large factor in the channels through which rice products pass from the manufacturer to the consumer. The parching industry is primarily a cottage industry, and the parchers themselves are, in the main, the chief agencies for the distribution of their products. There are, however, a number of large firms of merchants or *arhatiyas* in urban centres, who buy directly from local parchers and then distribute their purchases in the neighbourhood, or consign the same to distant consuming markets. These traders operate in the same way as their prototypes handling cereals, pulses, oilseeds and other agricultural produce. Some, in fact, market parched products as well as cereals, etc.

The internal trade resulting from local and inter-state movements by rail, river and road is also relatively small. The main directional movements seem to be normally from West Bengal to the adjacent areas of Bihar and Orissa, and from Uttar Pradesh to Delhi, the Punjab, parts of Madhya Pradesh and Rajasthan. There is, of course, a good deal of local trade in the above States as well as in Madhya Pradesh.

Rice products are consigned in jute bags (generally referred to as gunnies or gunny-bags) used by all sections of the trade handling agricultural produce. The most popular of these bags are the heavy 'C' and 'B' Twill measuring $40'' \times 28''$ and $44'' \times 26\frac{1}{2}''$, respectively. While beaten rice is normally transported in these coverings, parched paddy and parched rice, which are relatively lighter and more voluminous, are usually transported in larger sized bags, specially prepared by the consignors by sewing together used gunny sacking, preferably of the heavy 'C' type.

Official records of the prices of various rice products are not maintained, nor are any series of quotations for fairly long periods available from the trade. Enquiries, however, show that the relation between the prices of rice products and the raw material (rice or paddy from which they are made) is highly variable, and that the prices of rice products fluctuate much less than those of the raw materials.

The cost of distribution varies in different instances, depending upon the handling and transport involved. Generally, the railway freight constitutes the major portion of the distribution costs. It may be noted that parched rice is grouped under class 4 for purposes of railway freight so that the rate of freight for parched rice is higher than that of rice or other foodgrains, which are grouped under class I.

Retail. Most of the retail distribution of parched products is carried out by the manufacturers (*bharbhunjas*) themselves. The shop generally contains the oven and other parching equipment, the whole being placed in a courtyard or frequently in a verandah or in a room in the parcher's house, in such a position as to face a thoroughfare. Customers are served by the parcher himself or, if he is busy at the oven, by his wife or other members of his family. There is usually no bargaining as individual retail transactions are very small ranging from quantities worth anything between a few pice to a few annas.

In large towns, the distribution of rice products also takes place through retailers who purchase their supplies from parchers in wholesome lots. In addition to those retailers whose sole business lies in the sale of parched products, a number of grocers handling various cereal and pulse products, such as *atta* and *dal* as well as edible oils, etc., also keep small quantities of parched grains, including parched and beaten rice. A few provision shops in big cities retail high class beaten rice only for consumption by their well-to-do patrons.

Hawkers (*pheriwalas*) play an important role in the retail distribution of parched products of all kinds. In regard to rice products, this community has a special place in large urban centres, where parchers' establishments and the retail shops selling these products are not located in close proximity to thickly populated residential and shopping districts. The chief rice products handled by hawkers, especially during the season, are parched rice and ground parched rice (*sattu*), but small quantities of beaten rice and fried beaten rice are also hawked on the streets

throughout the year. Although it is estimated that about 25 per cent. of the total quantity of parched rice sold retail passes through the hands of itinerant vendors, some of whom, it may be noted, are themselves professional parchers and combine the two functions of manufacture and distribution.

PRICE MARGINS

The difference between the wholesale and retail prices of various rice products varies enormously. Of the three rice products, parched paddy generally carries the highest retail margin. This is due primarily to three reasons. In the first place, the demand has a distinctly seasonal aspect; consumption rising in the months in which a number of religious festivals occur, as for example, in October and November. Secondly, the commodity itself does not keep as well or as long as parched and beaten rice. Finally, the quantity manufactured is comparatively small.

Retail margins also vary according to the retailing agency. Products can usually be bought more cheaply directly from the parchers' establishments than from street hawkers. The latter sometimes retail their rice products at double the price at which they buy from the suppliers. For example, at Delhi, where street trading is apparently a flourishing occupation, if the number of itinerant vendors is any criterion, several hawkers are found retailing parched rice at double the current wholesale price.

PRODUCTION AND UTILIZATION OF SECONDARY PRODUCTS

The secondary products are mainly paddy husk and rice bran, which are by-products obtained in the process of rice-hulling.

The annual output of paddy husk in India may be estimated at an average of about ten million tons. A considerable proportion of this quantity is utilized as fuel in domestic cooking and for boilers in rice mills. A certain amount is consumed in admixture with rice bran by cattle and donkeys, as also for mixing with mud plaster as a 'binder'. The use of rice husk in the activated carbon process of *gur* manufacture appears to have some potentialities. It is also worthwhile investigating the possibilities of using rice husk in the preparation of furfurol for use in the manufacture of synthetic resins and in the fibre board etc.

Rice bran, the average annual production of which is roughly estimated to be about 1.69 million tons, should be of considerable commercial importance on account of its high nutritive quality as cattle feed, but it is frequently disposed of mixed with paddy husk and its full value is thus not always realised. The price of rice bran in some parts of India, as in the States of Kerala and Mysore are remarkably high, as compared with those in some other parts of India, as in the Punjab.

PART III

TECHNOLOGY

CHAPTER 32

SOME ASPECTS OF THE TECHNOLOGY OF RICE PROCESSING IN INDIA

The beginnings of the technological aspects of rice processing like milling, parboiling, etc., are to be found in the earliest traditional practices in the country. The practice of milling is as old as the cultivation of rice itself and has been referred to even in the *Vedas*. Different types of milling equipment for shelling and polishing of rice for household use existed in Indian homes many centuries ago. The time from which parboiling came into vogue is not known with certainty, although the technical and the nutritional advantages of parboiling were known to our ancients. It is thought that parboiling came into use mainly to facilitate the removal of the husk from paddy and to minimize its breakage during milling. Whatever be the reason, the discovery of parboiling is one of the most important achievements in food science and the credit for this discovery belongs to India. There is no record to show as to who first discovered the process, but there is no doubt that parboiling was being practised in India long before it was known in other parts of the world. The practice spread to different countries largely through the migration of Indians. It is unfortunate, however, that excepting for the discovery of the basic principle, no practical improvements were made in India until recently. The credit for the mechanization of the process should go to other countries especially to the United States of America.

Even now, parboiling and milling are two of the most important industries based on rice in India. Judging from the quantities of rice milled and parboiled (25 million tons for 1955-56), the turnover is so enormous that they can be regarded as some of the biggest food industries in India. There are about 2,000 registered rice mills in the country and their daily outturn of head rice ranges from half ton to 15 tons. It is a typical cottage or small-scale industry using machinery and power and is one of the most well-developed industries of its type in India. As the transportation of paddy over a long distance is costly, it is but natural that the rice mills are small-sized and are located around the regions of production. A considerable amount of experience has been gained in India on the technical and practical aspects of parboiling and milling, and it is the purpose of the present review to draw attention to these and allied aspects. Although milling and parboiling are allied industries, they are nevertheless different technical operations and will be treated accordingly.

PARBOILING OF RICE

Although parboiling has been practised in Indian households for hundreds of years, large commercial mills came into being only at the end of the last century. Parboiled rice as prepared in households in small quantities is generally less smelly or coloured and more attractive than that produced in commercial mills. The

household practice consists usually in raising the temperature of a mixture of paddy and water to the simmering or boiling point and allowing it to cool gradually. The soaking water is drained out and the paddy is dried. As it is usually dried in the shade and the drying is slow and uniform, the appearance of cracks on the grain is minimized and breakage during shelling is reduced. The paddy parboiled by the above method in the home usually gives a rice which is not completely gelatinized. An opaque core of raw starch can be seen at the centre of the grain and this is preferred by certain sections of the population. Such grains are not, however, as hard as fully parboiled rice of commerce and suffer higher breakage during milling.

Commercial Methods. Traditional commercial practices are based on similar principles taking into account the fact that the miller has to parboil large quantities at minimum expense. Two types of processes are widely employed in commercial practice in India. One is the Single Boiling process, where the paddy is soaked in cold water for two to four days and then steamed. The Double Boiling process adopts a preliminary soaking of the paddy in warm water before steaming. The object of soaking in warm water is mainly to reduce the soaking time.

Single Boiling. In the Cold Soaking or Single Boiling process, immersion for two to three days is considered necessary for a thorough penetration of water into the grain, for, otherwise, white-centred grains which are liable to suffer high breakage during milling would result. During this long soaking process, fermentation is bound to start and proceed to varying amounts depending upon the time of soaking and the amount of adventitious impurities associated with the paddy immersed. Frequent change of the soaking water may minimize this fermentation but would not completely eliminate it.

Double Boiling. In the Double Boiling process, dried paddy is steamed in batches and discharged into a large tank of cold water ; or alternately paddy is poured into a tank of warm water which has been pre-heated to about 60°C. In either case, the resultant temperature of the tank would be around 45°C. As the contents gradually cool and reach the temperature range of 30° to 40°C, they become an appropriate medium for proliferation of fungi and bacteria which begin to develop and impart an offensive smell to the tank contents. The fermented smell is mostly concentrated in the soaking water and a large amount of the smell can be eliminated by draining it off, but when the fermentation has proceeded to an advanced degree, the odour penetrates into the grain and is emitted during the steaming of the paddy and the subsequent cooking of the parboiled rice. Humid, cloudy and rainy weather for two to three days continuously during the drying period will also promote the accentuation of the characteristic fermented smell.

For these reasons, the quality of parboiled rice produced in commerce is not generally satisfactory. Some sections of consumers have got used to the fermented smell, but this arises largely through tolerance rather than to any special taste of the rice. In any case it is an avoidable smell.

Improvement of Current Methods of Parboiling. The prolonged and uncontrolled fermentation in the soaking tanks will affect adversely the colour, the swelling quality during cooking and also the nutritive value of the parboiled rice. These defects in the method of manufacture have been recognized in the past both

by the scientists and the Government. Charlton (1923) first drew attention to the nuisance caused by the commercial parboiling mills in India. The Rice Technology Committee of the former Ministry of Food sponsored a research programme for the study of this problem. Based on their work, Sanjiva Rao and Guha (1952) prepared a report recommending ways and means of improving the quality of parboiled rice. On the basis of the information available in this report, a more detailed study of the causes of the fermentation and its prevention by simple and practical methods was taken up at the Central Food Technological Research Institute, Mysore. On examination of the parboiling operation in several rice mills, it was found that the bad smell developed mostly during the soaking period. Although there is some further development of smell during drying, especially in thick layers during inclement weather, the main cause was the prolonged soaking. Attempts were therefore, directed towards eliminating the bad smell and the causes that gave rise to the bad smell by arresting the fermentation in the soaking tanks either by heat sterilization of the soaking water or by the addition to it of a permissible chemical to check the proliferation of fungi and bacteria.

Hot Soaking Method. The Hot Soaking method is similar to that employed in mechanized parboiling operations like the Malekized or the Converted Rice Processes. A steady maintenance of the soak water at 65°to 75°C will effectively control the growth of fungi and prevent the development of off-flavours. The soaking period can also be reduced to about two to three hours. The applicability of this method to large scale parboiling in mills was also studied and it was found that a practical method would be to add steamed paddy into warm water so that the resultant temperature would be about 65° to 70°C (Subrahmanyan, Desikachar and Bhatia 1955). This method could be adopted readily by all mills that have boiler facilities for raising and distribution of steam. In those mills where only a hot water kettle is available, hot water from the kettles could be directly tapped into the soaking tanks in order to raise and maintain their contents at the desired high temperature. The additional cost of steaming in this method has been found to be four annas more per 200 pounds of rice.

After the initial soaking, the steaming of paddy is at present a batch process. The paddy from the soaking tanks is transferred by head loads into cylindrical kettles provided with steam coils and then steamed in batches. It would be a saving in time and labour if the entire paddy in the soaking tank could be steamed in the tank itself. This could be achieved by running a steam coil through the soaking tank and providing it with an adequate steam distributor. The practicability of such a procedure was recently studied in commercial rice mills in Mysore and the following method has been found to be satisfactory and acceptable to rice millers.

Improved Hot Soaking Process. Using the same cement tank capable of taking a charge of 100 bags of paddy (10 tons), the hot soaking is carried out by fitting a steam distributor at the bottom of the tank. The required quantity of soaking water is put in and brought to a temperature of 80° to 85°C by steam and the paddy (100 *pallas*) is dumped in and raked. The paddy husk and light paddy which float on the surface of the water are skimmed off and the contents of the tank are left over for a period of three to four hours. The average temperature in the tank is

about 65° to 70°C during this period. At the end of this hot soaking period, the water is let out and the mass of paddy while still hot is steamed keeping the water discharge valve open at the bottom. Steam enters at the bottom of the tank and gradually permeates the entire mass. When steam emerges out from the top, the entire bed of paddy will have been uniformly parboiled. At this stage, it has got to be immediately removed from the tank ; otherwise, the residual heat in the thick layers tends to overcook the paddy. If no special means of removal of the paddy are available it has got to be shovelled out by labourers who could be provided with heat-resistant foot-wear. The paddy is then spread out as usual for drying, and milled.

The following are the advantages of this method.

1. The resulting rice is of an excellent quality with a fine translucent appearance, pale yellow colour and absolutely free from any off-flavour. The soaking tanks and the mill premises could be kept clean and hygienic. The surrounding locality will also not be polluted by the foul smell which is emitted at present both when the soaking water is discharged and the soaked paddy is steamed.
2. Less labour is involved in this method because the soaking and the parboiling are done in the same tank.
3. Much time is saved ; in contrast to three days involved in cold water soaking, only three to four hours soaking is involved in this method and therefore, more paddy could be parboiled per tank than by the Cold Soaking method, during the same period.
4. There is also a saving in power or labour charges in connection with pumping the large amounts of water needed in the customary Cold Soaking process. In places where there is water scarcity, the proposed method will be specially advantageous.
5. The suggested modifications to the soaking tank are simple and reasonably cheap.
6. As the paddy will have been more or less sterile by the hot soaking and subsequent steaming treatments, the microbial load on the paddy is very small and hence it is less likely to develop bad smell during drying as compared with the paddy treated according to the Cold Soaking process.

Further Improvements Desired. It has been indicated that after the completion of the parboiling, the hot paddy is to be immediately baled out of the tank. This is done at present, as a purely temporary expediency by labourers standing on the hot paddy, using heat-proof footwear. This is hardly the right thing to do, especially from the human point of view. If the tank is built a little above the ground level with a trap door at the bottom or the present tank is modified to have a trap door to draw off the paddy, it will be the obvious solution. This is being investigated, and a rice miller who is constructing a new tank, will incorporate this improvement with the technical help provided by the Central Food Technological Research Institute.

Hypochlorite Treatment. Among the chemicals studied for preventing the growth of fungi and bacteria, it was found that addition of sodium hypochlorite is

effective in controlling the growth of the micro-organisms mainly responsible for the bad smell (Desikachar, Majumdar, Pingale, Swaminathan and Subrahmanyan, 1955). In the doses used, sodium hypochlorite did not effect the appearance, cooking quality, or the protein nutritive value of the rice. The sodium hypochlorite used in earlier experiments was a solution. The suitability of a stable solid soda bleach mixture has been studied more recently. Such a material has been found to be suitable for controlling the micro-organisms. With proper standardization of conditions, hypochlorite mixture can be used by small and big mills alike for producing parboiled rice of high quality. This would involve no change in the present method except the addition of the chemical to the soak water. It would, however, slightly increase the cost.

Mechanization of Parboiling. The possibility of complete mechanization of the parboiling operation, especially for the drying process has often come up for consideration. There is no doubt that mechanization would be clean, eliminate a lot of unhygienic processing and thus help to produce a wholesome hygienic product acceptable to all consumers of rice. As already indicated, the parboiling industry is of a cottage scale type and generally the initial capital outlay on a commercial mechanical drying equipment is beyond the capacity of the majority of the rice millers. Mechanical drying would, however, be a necessity in places where there is wet and rainy weather for a large part of the year or in places along the sea coast where high humidity retards the rate of drying. As private millers may not be forthcoming to invest capital on mechanization of the process, governmental and cooperative agencies have to make a beginning and demonstrate the technical advantages of a mechanized equipment both for parboiling and for drying. A beginning could be made in a few Community Development Centres.

Over a considerable part of India, the present methods of parboiling can give a fairly satisfactory product if the necessary pre-heating or soak water treatment can be adopted. Sun-drying may be adequate for a large part of the year. The mechanical drier will, however, be essential as already indicated in certain areas where there is a risk of spoilage or serious loss of quality. There is need to develop simple and comparatively inexpensive methods of drying applicable to such conditions.

RICE MILLING

The problem can be considered under two heads: (i) milling of parboiled rice and (ii) milling of raw rice. With respect to the former, there are no difficulties because the breakage during milling of parboiled rice is very little due to the hardness of the parboiled grain. It is for this reason that the yield of head rice as a result of parboiling is about five to ten per cent. more than that obtained in the case of the milling of raw rice. This adds to the rice resources of the country, and should be taken note of in times of emergency as a method of making better utilization of the available rice supplies. This increased yield more than pays for the cost of the parboiling. The coarse and medium grained varieties of rice are generally employed for parboiling in South India, although the fine and hard grained varieties are used in the North. From the nutritional point of view also, the milling of parboiled rice

presents less difficulty because the loss of nutrients during polishing is at a less rapid rate than in the case of raw rice. It should be noted, however, that parboiled rice will also suffer loss of nutrients if the polishing is carried too far.

The milling of raw rice presents two difficulties as compared with the milling of parboiled rice. These are: (i) a comparatively greater breakage of the grain during milling and (ii) a considerable loss of minerals and the B-vitamins if the grain is polished beyond about five to seven per cent.

The coarse and soft varieties suffer high breakage and are rarely milled in the raw condition. As already indicated, they are usually parboiled before milling. It has been shown that breakage can be minimized provided the paddy has been previously dried and reconditioned to an optimum moisture content. The type of mechanical equipment used for milling also determines the amount of breakage. The commercial ' Huller ' type machines that combine shelling and polishing in one operation usually produce considerable breakage. This results in a lot of broken rice as a by-product which would naturally fetch a lower price. In such types of machines, where the paddy passes through a sheller for the removal of husk and then undergoes a subsequent polishing in one or more polishing cones, there is generally less breakage and these are the types of machines that are now increasingly employed in commerce for the milling of raw rice. An advantage of the latter type of equipment as compared with the ' Hullers ' is that the operation is automatic and fine control of the degree of milling can be obtained. The ' Huller ' type machines are not also provided with a paddy separator. In these machines, while over polishing results in high breakage of the grains, underpolishing results in considerable admixture with intact paddy. In view of these disadvantages and difficulties attending the use of such ' Huller ', the Government is trying to discourage their use by withholding permits for installation of new machines. Such machines as already exist can be largely used for the milling of parboiled rice.

There is also the need for effecting improvements in the design of milling equipment with a view to minimising breakage and effecting an increased return of head rice. Fair amount of work is already being done in this direction and some of the types of machinery fabricated in India will be discussed in the following section.

RICE MILLING MACHINERY USED IN INDIA

As already indicated, there are two main types of machines used for rice milling—the ' Hullers ' and the automatic rice milling machines. There are about 20,000 ' Hullers ' while the automatic mills number about 3,000. Although, in the initial stages all the rice milling machinery was imported either from the U.K. or from Germany, rice mills can now be built entirely by Indian manufacturers. Several concerns manufacturing the milling machinery have sprung up. We are thankful to Messrs Dandekars who are one of the leading manufacturers in the line, for some valuable information which has been useful in the preparation of the present section.

The Huller. The machine was originally designed for removing the outer hulls of coffee, but later adopted for the milling of rice. The machine consists of a solid fluted cylinder rotating at 500 to 600 r.p.m. within a hollow stationary cylin-

FIG. 48. Paddy being steamed in the steaming kettles

FIG. 49. A general view of the paddy-soaking tanks, steaming kettles and the drying field in a Rice Parboiling Mill. The storage godowns can be seen in the background

FIG. 50. Paddy is being turned over by the workers during the drying process

FIG. 51. A hand-raker being used for even spreading of the paddy while drying

der the lower half of which is perforated with slots of 0.06 to 0.3 inches. The flute on the cylinder is so arranged as to carry the paddy to the centre from the feeding end, get it milled by the scouring action at the centre of the cylinder and then carry it to the other end where milled rice is discharged. The grain suffers excessive breakage and gets overheated due to friction. Power consumption is large as energy is wasted in crushing of hulls and grain and creating heat instead of simply splitting the hulls.

Automatic Rice Mill. Paddy is first discharged by means of an elevator on to a set of cleaning sieves from which it gets freed of stone, straw, dust, grit, etc. It is then husked in the sheller and the shelled paddy is freed of husk in a husk separator. The paddy from the mixture of rice and paddy (remaining unhusked) is removed in the paddy separators and the shelled rice is carried by elevators into a storage chamber from which the rice can be fed to a series of polishing cones for the polishing of the rice. The polished rice is delivered by an elevator to a sorting sieve where head rice and broken grains are separated and later collected separately. A brief description of the various units is given below.

Elevator. It consists of sheet metal top and bottom with belt pulleys at both ends carrying the belt and buckets for elevating the grain. Belt tightening arrangement is provided at the bottom while driving is provided at the top pulley.

Aspiration Cleaning Sieve. A mild steel suction fan is connected to the aspiration box where the antiflow of air sucks out chaff, dirt, etc., from the paddy. The cleaning sieve is of reciprocating type and has horizontal strokes of 5/8'' arranged by eccentric running at about 300 r.p.m.

Sheller. The sheller is of the under-runner disc type varying in diameter from 18 to 56 inches. The lower runner disc could be lowered or raised by two hand wheels at the base of the machine. A Micro-adjustment of distance between the running and stationary disc is possible.

Husk Separator. An aspirator sucks out the husk and by means of a long tube can throw out the husk to a distance of 40 to 50 feet. An expansion chamber is provided in the passage of the husk so that any rice that is initially sucked by the air drops down and can be collected.

Paddy Separator. It consists of a shaking inclined wooden box divided into many compartments in three tiers. Paddy is discharged at the top end while the heavy rice is collected at the bottom. A taper pulley arrangement allows the variation of speed of shaking through a rack and pinion operated belt shifter.

Rice Polishing Cones. They consist of a set of inverted truncated cones covered with a mixture of emery and cement. The cone revolves on a vertical shaft inside a steel wire screen running nearly parallel to it. The annular opening between the cone and the wire cage can be adjusted by raising or lowering the revolving cone. The emery grains and the rubber breaks, however, are soft and easily wear out and have to be occasionally replaced.

METHODS OF MILLING CONTROL

The control of the degree of milling becomes necessary in the milling of raw rice. Mechanical methods of control are possible. In the cone polisher, the degree

of milling is controlled by varying the clearance of the polishing cone from the wire basket between which the rice grains undergo abrasion and get polished. Mechanical control of the degree of polishing was also sought to be effected by varying the r.p.m. of the motor running the cone polisher. From available reports it appears that no significant progress has been made in controlling the degree of milling by these means.

Thiamine Assay. Among the chemical methods for assessing the degree of polishing, determination of thiamine in the grains is the most important. Methods of thiamine assay most commonly used are based on measurement of the fluorescence of thiochrome (Hennessey and Cerecedo 1939). Colorimetric methods using a coupling reaction between thiamine and diazotised p. amino acetophenone have also been described recently by Hockberg, Melnick and Oser (1945). An accurate thiamine assay by either of these methods is time consuming. Modifications of these methods to effect a saving in time, especially in the extraction of the thiamine have been worked out by Kik (1945) and Desikachar (1955a). These would be of considerable use in the routine assay of thiamine in samples of rice.

Phosphorus Content of Rice. Phosphorus content of the grain has also been proposed to be used as a means of characterizing the degree of polishing by Aykroyd *et al.* (1940). and Desikachar (1955 a). Allowance has to be made for varietal differences in phosphorus content. In order to allow for these differences, the degree of milling could be expressed in terms of the percentage loss of phosphorus as a result of polishing, rather than in terms of the absolute phosphorus content of the polished grain (Desikachar 1956a). A correlation between thiamine and phosphorus content has been shown to exist [Desikachar 1955 (a) 1955 (c) and 1956 (a)]. Methods for comparative assay of phosphorus in rice samples that can be completed in about 20 minutes have been worked out at the Central Food Technological Research Institute, Mysore. It has been shown that a preliminary five minute digestion of rice with concentrated sulphuric acid would release 90 to 95 per cent. of the phosphorus which can be estimated by a colorimetric method (Desikachar 1955a).

Colorimetric Methods based on Bran Pigments. The possibilities of using other simple colorimetric methods for qualitative and semi-quantitative assessment of the degree of milling have also been worked out at the above Institute. The natural admixture of commercial varieties of paddy with a small percentage of coloured grains has been taken advantage of in one of these methods. As the coloured varieties have a red, brown or purple pericarp, the degree of bran removal can be judged qualitatively. These bran pigments could be extracted with warm sodium carbonate solution and the intensity of the extracted colour gives a measure of the amount of polishing the sample has undergone during milling. The colour shade of the grain, therefore, acts as a natural indicator of the degree of milling (Desikachar 1955 b). The differential staining characteristics of the rice bran and the endosperm have also been demonstrated (Desikachar 1955c). The amount of colour absorbed by the rice grain could later on be extracted and the colour intensity of the solution could give a comparative idea of the degree of milling of the grain. The bran from even the non-coloured varieties has been found to give a yellow colour when treated with dilute acid and sodium nitrite and this solution was found to

turn pink when made alkaline. The intensity of the colour progressively diminished with increasing degree of polishing of the rice. This ' Alkaline nitrite ' test has been standardised for semi-quantitative work by Desikachar (1955c). Bran pigments also give a brown colour when treated with methanol in alkaline solution. The possibility of using this method for determination of the degree of polishing has been demonstrated.

These methods of determining the degree of polishing are of indirect value. The object of milling control is mainly to conserve vitamin B_1 in the rice. Hence, it is most logical to assess the degree of polishing mainly on the basis of the thiamine content of the rice. These indirect methods are, however, useful for rapid and comparative assessment in processing control of rice milling. Their main advantage is that they are simple and can be completed in about 15 to 30 minutes and the methods suggested do not involve the use of costly chemicals or equipment.

Control of polishing is undoubtedly of some value, but a more important thing is to educate the consumer to develop a taste for under-milled rice. As things stand, there is nothing to prevent a consumer from further polishing the grain after purchase. A still more important thing is to develop a variety of rice which will have all the desirable commercial qualities and at the same time possess sufficient margin of essential vitamins and minerals so that even after polishing, the consumer will still get at least the minimum quantity of thiamine needed to prevent beriberi.

HAND-POUNDING

Milling of rice in small quantities in the village homes using the various types of traditional equipment comes under the collective term ' hand-pounding'. The chief virtue of hand-pounding is that it gives a medium polished rice with a high thiamine content. It also provides some employment and helps in the maintenance of the village economy. However, certain disadvantages of hand-pounding as compared with machine milling have to be pointed out in this connection. The breakage of grains in hand-pounding may sometimes be greater than in machine milling because the abrasion in hand-pounding is less uniform, though more gentle, than in mechanical milling. From the technological point of view, machine milling with adequate safeguards for preventing over polishing and with gadgets for fine control of the degree of polishing is to be preferred.

Improvement of the traditional equipment for hand-pounding should also be effected with a view to increasing the efficiency of milling, reducing breakage to the minimum and mitigating the hardness of severity to the human worker engaged in hand-pounding. Milling by the ' Pestle and Mortar ' type equipment involves heavy manual labour and the amount of broken grains is usually high. The ' *Chakki* ' type equipment which is essentially a wooden or stone grinder operated by hand is more efficient than the Pestle and Mortar type equipment and it gives a product with few broken grains. It, however, produces only unpolished rice and this has to be polished again using a ' Pestle and Mortar ' equipment. If the grinder type equipment could be modified as to increase the severity of the abrasion during the grinding operation, an underpolished rice that could straightway be used by

consumers could be obtained. The use of a hand wheel for being attached to the stone or wooden grinder to reduce the severity of the operation and to lessen the friction during rotation should be considered.

UTILIZATION OF BY-PRODUCTS OF RICE MILLING

Hulls. The chief by-products of the milling industry are hulls, bran and broken rice. Although the calorific value of the hulls is low because of its high ash content, it is being used by the millers as a fuel for raising the steam necessary for the parboiling and in some cases for running their milling machines. Very little extra fuel is used for the boilers in most places. The possibilities of using the hulls for insulating boards should be examined. The high abrasive action of the hulls is well known. The rice millers are making use of this property in the polishing of rice. Small quantities of the hulls are mixed with the shelled rice before it goes to the cone polisher. The hulls have found use as an abrasive material especially in the polishing of parboiled rice which is very hard and offers resistance to easy polishing.

Bran. Bran is the most important by-product of the rice milling industry. The milling of rice using the 'Huller' type equipment gives a mixture of bran and hulls and a separation of the two by sieving is necessary. The cone polisher, however, gives a fairly clean bran free from hulls because the rice has been freed from hulls before it enters the polisher. The composition of the bran depends upon the degree of extraction during milling. The higher the degree of polishing of the rice, the greater is the content of carbohydrate material in the bran. In view of its protein, fat, starch and cellulose contents, the bran has a good food value for milch animals and is being used as such throughout the country. The bran from milling of raw rice is nutritionally richer than that from parboiled rice and is, therefore, costlier.

The industrial utilization of rice bran instead of or in addition to its use as an animal feed is an important subject for study because of the very valuable constituents present in it. Rice bran contains 18 to 20 per cent., edible oil. The possibilities of extracting the oil by the Solvent Extraction process, using alcohol as solvent have been studied by Raghunatha Rao and Krishna Murthy (1955) and Raghunatha Rao (1956 and 1957) in the Central Food Technological Research Institute, Mysore. Studies on a pilot plan scale have been made recently confirming the laboratory findings and proving the economic feasibility of manufacture. Production on a commercial scale under Government auspices is contemplated. Hexane is the industrial solvent normally used in most countries, but since alcohol is the cheapest solvent abundantly available in India, the extraction of rice bran oil using alcohol as the solvent promises to be an economic proposition. Rice bran is also a rich source of most of the B-complex Group vitamins and the preparation of vitamin concentrates from rice bran needs to be standardized, so that it could form an adjunct to the rice bran oil industry. The possibilities of the feed value of the extracted rice bran residue to animals has to be explored for including it as a positive factor contributing to the economics of this integrated industry.

Rice bran oil industry is already developed in other countries, especially in U.S.A. and Japan. India has vast supplies of rice bran. It should not be difficult

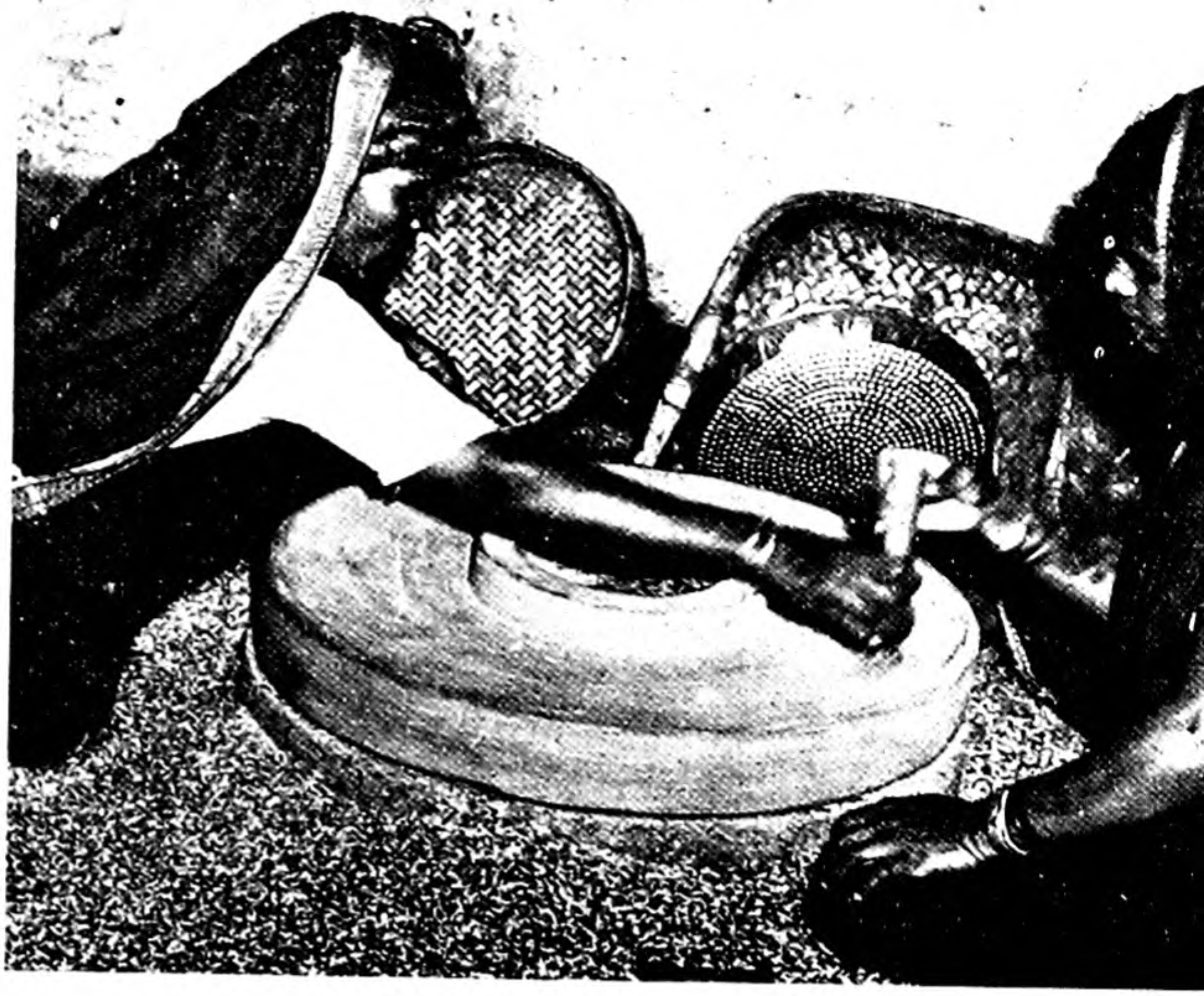


FIG. 52. Paddy being husked in a stone hand-grinder

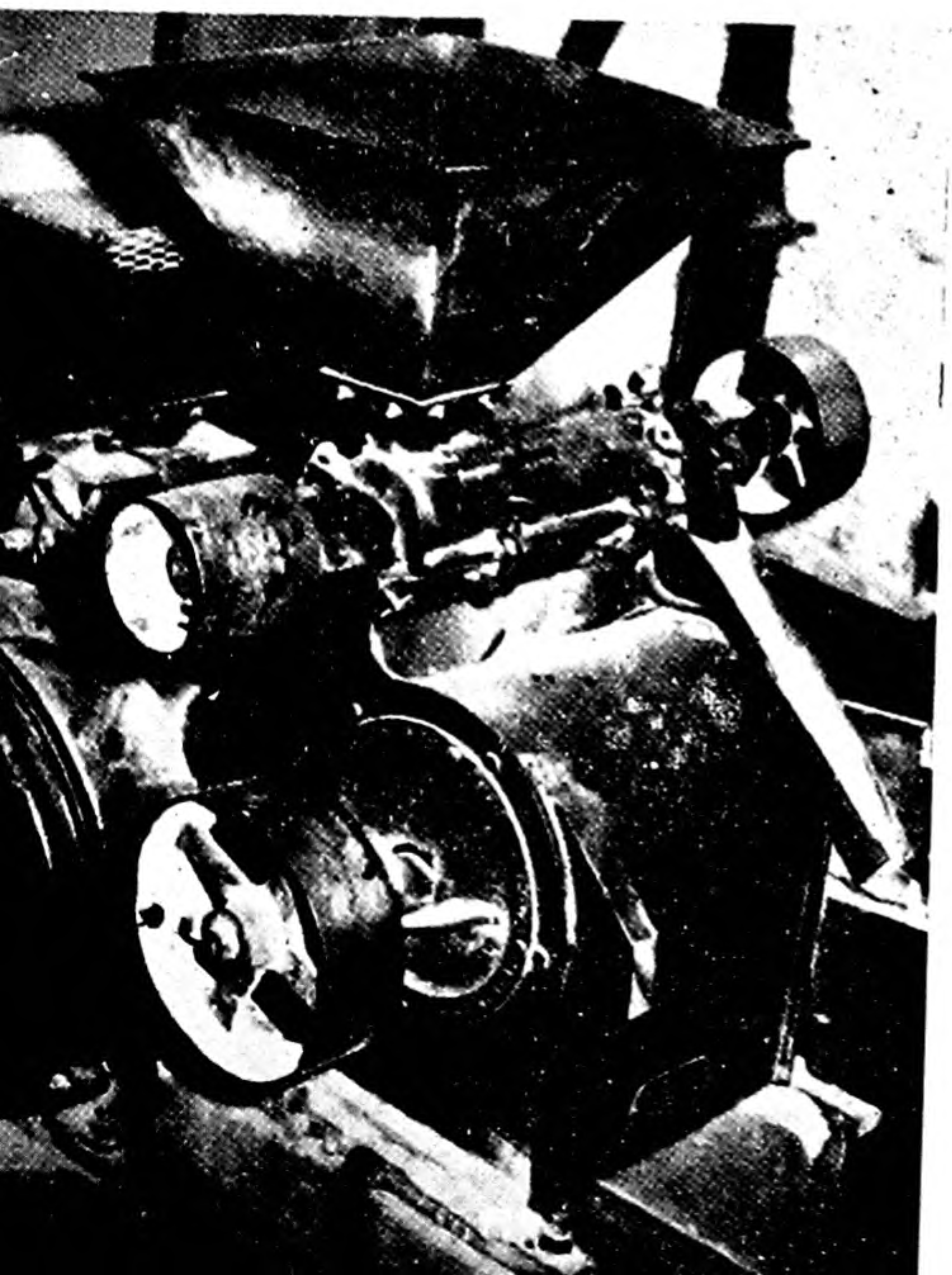


FIG. 53. A huller type machine commonly used for milling small quantities of paddy

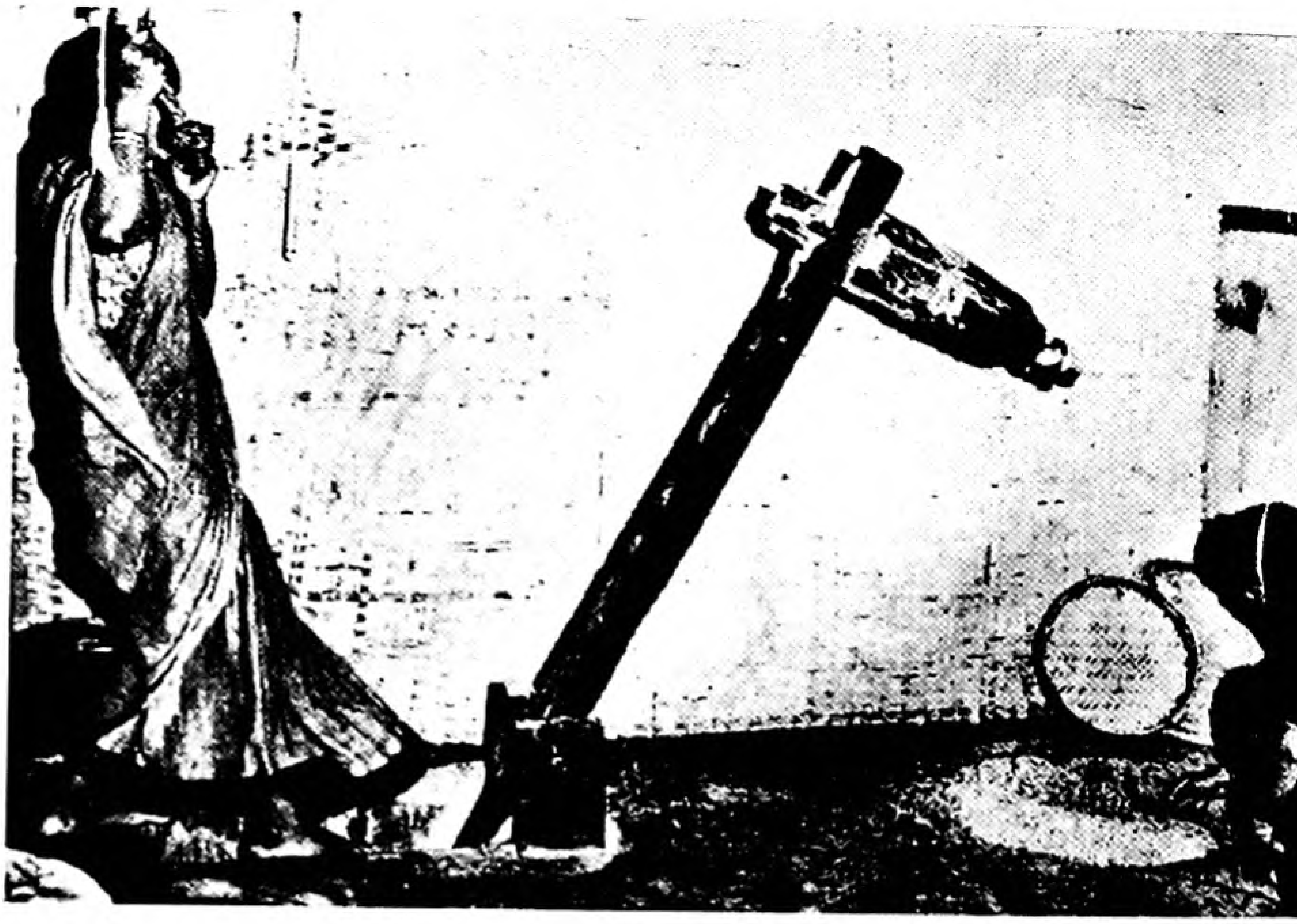


Fig. 54. A foot-operated pounder used for milling rice

Fig. 55. A hand-pounder

Fig. 56. A hand-operated fan for removing husk and chaff from the milled rice

to organize the industry on a co-operative basis, especially in some of the intensive rice-growing areas. The bran should be collected as fresh as possible and extracted in the shortest possible time, for, otherwise, there will be pronounced lipase action accompanied by increase in free fatty acid. Alternatively, the lipase has to be inactivated immediately after the bran is collected from the mill by heating and drying it.

Broken Rice. Broken rice is usually obtained in the milling of raw rice, though improperly dried or overdried parboiled paddy also gives broken grains. Broken rice as such has a low commercial value although from the nutritive point of view, it may be as good as whole rice. Low grade samples are fed to poultry or milch animals while good grades are used after powdering or wet-grinding for the preparation of rice dishes in households. The chief difficulty in its use is the removal of grit and stones usually associated with it. These could be reduced by including a separator for sifting the paddy from stone and grit before it passes through the shelling operation. Clean broken rice of graded size can be used and is being used as rice semolina for making traditional savoury or sweet preparations like *Uppumav*, *Halwai*, etc.

The possibility of reconstituting the broken rice into the original rice shaped grain has also been studied in the Central Food Technological Research Institute, Mysore. After a preliminary heat-treatment of the broken rice, it has been found possible to reconstitute the grains into a product which has the properties, shape appearance and cooking properties of parboiled rice. It, however, takes a shorter time for cooking than normal parboiled rice. In the reconstitution process, the mix can be fortified and enriched with vitamins, minerals and other deficient nutrients for the use of convalescents among the rice eaters.

At present, there is no strict specification in India regarding the permissible limit for broken rice along with the whole rice. As a result of this, a substantial part of the broken rice is actually sold along with whole rice. In other countries, however, there are strict specifications especially in regard to rice for export. In such countries, utilization of broken rice is a serious problem and scientific reconstitution into whole grain will be of great practical value.

BREAKFAST FOODS AND READY-TO-SERVE DISHES

Puffed Rice. Many types of processed ready-to-serve foods from rice have been known in India from thousands of years. The earliest known and the most easy to prepare is puffed or popped rice. The increase in volume by puffing is considerable and the puffed rice is very porous. It becomes very soft in a few minutes when wetted. Mixed with milk, buttermilk etc., it is a ready-to-serve food and is reputed for its easy digestibility. Puffing is a very easy way of removing the husk from the paddy and it may be for this reason that it is the oldest known ready-to-serve dish common in India.

Beaten Rice. Beaten rice in various forms is another popular processed food from rice. It is a type of fully parboiled rice which has been made flat and thin by pressure as to form flakes. If the pressure after the gelatinization of the rice is sufficiently intense, very thin flakes could be obtained. If further improved by addi-

tion of suitable flavours and sweetening agents, rice flakes are bound to become very popular and could seriously compete with corn flakes as a breakfast dish. Roller devices that could exert a sufficiently intense pressure to flatten the rice grains would be necessary for the purpose of mechanising the flaking process. In traditional flaking methods, husked rice is used and hence vitamin losses are reduced. Beaten rice would, therefore, be equivalent to parboiled rice in its vitamin value.

Rice Crispies. Rice crispies prepared from dry toasting of beaten rice is another popular dish from rice. It is also used after being fried in oil. A problem in the use of rice crispies is to prevent its sogginess resulting from absorption of moisture from the humid air. Suitable types of packaging materials would be required for special packing of this food.

Other processed foods of an allied type include rice vermicelli, rice *papads*, rice curls, etc. These are usually prepared from rice flour prepared from broken rice. The flour is made into a paste with water and steamed to cook the rice partially as well as to give the properties of a dough to the mixture. The gelatinization of the starch gives stickiness and extensibility to the dough. The dough is seasoned and then extruded through a hand press to get strands or curls of flakes, and these are dried in the sun and later on used after frying in oil. The admixture of rice flour with blackgram flour (*Phaseolus radiatus* L.) to give extensibility to the dough is also common in many homes.

All these processed foods from rice are known in the Indian household, but there are very few factories processing and packing them for the consumption of the public. As there is a definite and ready internal market for these processed foods, any industry processing them and offering them to the consumers in a wholesome, hygienic and attractive form has a bright future provided the products are reasonably priced.

Instant Rice, Canned Rice, etc. Other easy-to-serve foods from rice include 'Instant Rice' and 'Canned Rice.' These are likely to be of value only for specialized purposes or under conditions of emergency. In situation where a saving in time is desired or for those situated at very high altitudes, such pre-cooked rice is of great value. Methods for the preparation of 'Instant Rice' on a laboratory scale have been standardized at the Central Food Technological Research Institute, Mysore. The Defence Science Organization has also done valuable work in this line.

Pre-cooked and dried rice that can cook very quickly is already on the market in the U.S.A. Such products will naturally be costly and they have to be packed with care.

An alternative method of shortening the cooking time of rice or any other grain would be to start with the powdered material and then to reconstitute it under pressure with an extruding press. In such a case, the cooking time can be reduced about a fourth of the normal time. In some cases, even treatment with boiling water will suffice to yield a cooked grain. Considerable amount of work in this direction has been done at the Central Food Technological Research Institute, Mysore.

FERMENTED RICE DISHES

Idlis, Dosais, etc. Completely fermented rice preparations of the type of sauces and beverages are not common in India although they are popular in China,

Japan and other Far Eastern countries. Preparations made from incipiently fermented rice are, however, common and peculiar to India, especially in the South. Preparations like *Dosais* (rice cake), *Idlis* (rice pudding), etc., are prepared from a mixture of rice and a pulse (black gram—*Phaseolus radiatus* L.). The mixture of rice and pulse is either ground in the wet state or the dry mix is made into a paste with water and then allowed to ferment for 8 to 12 hours and then toasted in the pan or cooked in steam (Lewis and Johar 1953). The fermenting organisms that form lactic acid and carbon dioxide are present on both the grains, but the fermenting medium is essentially the gram material, the protein of which helps in the raising of the dough. The fermentation should go to the right extent, for, otherwise, there may be poor raising or off-flavours may develop. Parboiled rice is better suited for the fermentation than raw rice. The black gram should be decuticled and should be fresh and finely ground. The fermentation proceeds well at about 35°C and when it is warm even overnight standing will suffice. When the atmospheric temperature is low, the dough should be preferably made up with hot water and kept in a warm place. If the dough is left in the cold, the fermentation makes very little progress even after some days and the resulting products are generally hard and unpalatable.

The use of fermented rice dishes—especially the *Idli* and the *Dosai*—is gradually spreading not only to other parts of India, but also to other parts of the World. First, it is an elegant method of leavening in which no external inoculum is needed. Secondly, the mixture of rice and pulse (generally 3 :1) is nutritionally well balanced and the fermenting organisms further enrich the dough with vitamins which they produce. Thirdly, the products—especially *Idli* which is steam-cooked—are very easily digested besides being quite palatable.

According to the traditional South Indian method, both the rice and the pulse have to be first ground separately, in wet state. The grinding of the gram to fine, smooth paste is considered very important. Such operations would be easy on a small scale, but they would be highly strenuous in big hotels and restaurants. When grinding has to be done on a big scale, there are mechanical devices available. The most satisfactory procedure will be to have ready-made dry mix that only requires to be stirred with hot or cold water and allowed to stand.

Suitability of Parboiled Rice for such Dishes. One obvious advantage of using parboiled rice in such a preparation lies in the cooked product becoming soft without becoming sticky. Even in parboiled rice, the preparations made out of certain varieties are considered to be better than others. Although they may appear to be empirical selections, there is a good deal of practical experience behind such a choice. If there is any excess dissolution of starch during steaming, the starch particles will tend to stick together. This may interfere with the raising of the dough during steaming. Raw rice, especially from soft and glutinous varieties will be unsuitable for such a purpose.

A great deal of scientific work has already been done by Johar and Lewis (1953) at Mysore and also by Dr. Radhakrishna Rao and his associates at Bombay. Further work bearing on the chemical and biological aspects of the fermentation and also methods of controlling it would lead to findings of practical value. The

process has not so far been applied to other cereals and millets and it would be of interest to extend the application. The possibility of making baked products which should have better keeping quality may also deserve studying.

Cold Rice. Another interesting practice prevailing in different parts of South India is the use of the 'cold' rice or water-soaked rice. Cooked rice is soaked under water overnight and consumed the next day. Such a rice is believed to possess special medicinal properties. It is considered 'cooling' to the system. The origin of its use is not known. Probably it arose as a method of preserving the rice for the next day in very hot weather. Soaking in a large amount of cold water should have helped in minimizing the fermentation. Incipient fermentation does, however, occur in the submerged rice and is believed to improve the flavour and taste. Soaking under water will also prevent the surface hardening of the cooked rice on keeping. As cooked raw rice will become very soft and soggy when soaked under water, only parboiled rice is considered suitable for the preparation of 'cold rice.'

Shonti Annam. Unlike China, Japan and other Far Eastern countries, fermentation methods based on the application of moulds and yeasts either singly or jointly are not commonly practised in India. There are, however, certain traditional fermentation methods, adopted in the north-eastern regions especially by the hill tribes. This may have developed through contact with China. There are also small pockets in the southern parts of India where symbiotic fermentation of rice is practised. One such preparation is the *Shonti annam* which is prepared in some parts of Andhra Pradesh especially in the Nellore District. The inoculum for the fermentation is generally collected on paddy husk or some other inert material which is dried into balls. These balls are broken up and distributed on cooked rice. The fermentation is brought about through the combined action of Rhizopus (*Rhizophus sontii*) and some species of yeast. The preparation has a pleasing aroma and taste and it is considered to be exceedingly wholesome especially in hot weather. If, however, the fermentation is carried out beyond the minimum period, the rice starts disintegrating forming a yellowish liquid with a pronounced alcoholic odour. The product is known to be mildly intoxicating (Rami Reddy and Subrahmanyan, 1937).

The use of certain moulds especially *Aspergillus oryzae* for the partial digestion of rice either by itself or in combination with certain pulses may be desirable as food for infants and invalids. The method must be standardized and the preparations demonstrated as a part of the Extension service in the country.

PROPERTIES OF SOME SPECIAL VARIETIES

These belong to the category of waxy and glutinous varieties and are usually short term varieties grown as summer crops. They have special cooking and adhesive properties suited for making 'puddings'. The starch from the waxy varieties differs from other common types in being almost completely in the form of amylopectin [Brown *et al.* (1948) & Sanjiva Rao *et al.* (1952)]. Special mention should be made of a glutinous variety called '*Puttu* rice' in Madras State and 'Soft rice' (*Komal chaval*—Hindusthani) in Assam.

The latter variety is called 'soft rice' because it can be cooked very easily to a soft consistency. A customary practice adopted in Assam is to wet the paddy in water and heat it slowly over a low heat until the paddy gets soft. The paddy is then dried in the shade or sun and then hand-pounded. The rice obtained from the above process is called soft rice because the rice need not be recooked before use, but can be soaked in water or milk and used straightway as a palatable food. While parboiled rice from ordinary varieties needs a prolonged cooking in boiling water, the soft rice needs only to be soaked in cold water before use. The physical and chemical properties of the starch and protein constituents of such varieties need to be studied to explain their cooking properties.

THE PROBLEM OF NEW VERSUS OLD RICE

It is the experience of rice eaters that rice obtained from paddy immediately after harvest has poor cooking qualities. It cooks to a pasty mass, does not swell completely during cooking and yields a thick viscous gruel. These undesirable qualities are eliminated by storage for a period of about six months after harvest. The high amylase content of the fresh rice or the colloidal properties of the fresh rice have been considered responsible for its poor cooking properties by Sreenivasan (1939) and Sanjiva Rao (1938) respectively. Changes in the physico-chemical properties of the amylase from fresh and old rice have also been recently noted by Desikachar (1956 b).

In regions where surplus rice could be had in plenty, it is practicable to use only old stored rice. But as enough supplies of old rice are not available, people have been forced, in recent years, to use fresh rice itself. Although various empirical culinary practices have been used to improve the cooking quality of the fresh rice there is need for a foolproof and simple method of curing of the fresh paddy or rice so that it could be used soon after harvest.

With this end in view, researches have been undertaken at the Central Food Technological Research Institute and simple methods of curing both for domestic as well as for commercial use have been developed. The methods employ the principle of 'wet-heat' conditioning of the paddy or rice to impart hardness to the grain so that disintegration of starch granules into the cooking water leading to pastiness is prevented. In the domestic curing method, the soaked raw rice is steam-cooked for about ten minutes immediately prior to cooking. A simple rice cooker where the steaming and the subsequent cooking could be done in the same vessel has been devised (Desikachar and Subrahmanyan 1957 a & b).

In the commercial curing method, the fresh paddy containing about 20 per cent. moisture is steamed for about 15 minutes and allowed to stand hot in a heap for about an hour. It is then dried by aeration preferably in the shade or mild sun and then milled. As the paddy has not been soaked in water prior to steaming, complete gelatinization of the starch leading to translucency and yellow colour characteristic of parboiled rice does not occur. The rice from paddy thus cured is opaque and looks like raw rice itself but it has the cooking qualities of old stored rice. The steaming treatment induces a certain amount of vitamin penetration into the grain and hence the cured raw rice also possesses a higher thiamine content than

the untreated rice. This curing method is, therefore, an excellent means of supplying raw rice of higher vitamin content to those accustomed to use raw rice.

OTHER PROBLEMS OF STORAGE

Although this problem will not be discussed in detail here, brief mention should be made of the technological aspects of storage which include the design of suitable containers for large scale storage over a long period. The design of suitable drying and aerating equipment for the reduction of moisture in the wet paddy prior to storage is also a very important problem.

CONCLUSION

As indicated in the review, a number of processed rice products have been known and used by people in this country for many centuries. What is specially needed is to standardize their methods of production, storage and distribution so that they are available to the consumers in a wholesome condition at a minimum cost. Wherever possible, mechanization may be introduced to increase efficiency and to conserve the nutritive value. Complete mechanization cannot, however, be the immediate goal, and there is a strong case for providing employment for the maximum number of people, without necessarily increasing the cost of the consumer, or lowering the quality of the product. The fixing of suitable standards for quality and a machinery for enforcing these standards should also be seriously considered. In a country where rice is staple food for more than half its population, the importance of the aforesaid problems cannot be overemphasized.

CHAPTER 33

NUTRITIVE VALUE OF RICE AND RICE DIETS AND THEIR NUTRITIONAL IMPROVEMENT

This subject is of very great importance because rice is the staple diet for over half the population of the world. In India, it forms the chief article of food for about half the population and in certain parts of the country, even people accustomed to other grains are steadily changing over to rice. The popularity of rice with the consumers is due to (i) its attractive colour and shape combined with the ease of cooking, (ii) its neutral taste and flavour so that it can go into a variety of sweet and savoury dishes and (iii) its capacity for filling and giving satisfaction without being heavy, to the consumer. It is because of these qualities that the consumers are able to take relatively large quantities of rice either in a single course or a succession of courses, without having a feeling of monotony. In many parts of India and especially the rural areas, it is not uncommon to see a consumer taking 1½ to 2 pounds or more of the equivalent of rice, that is four to six pounds in the cooked form.

The subject of the nutritive value of rice and rice diets has naturally attracted a good deal of attention. A large volume of work has been done on various aspects of the subject in India during the past three decades. Some excellent reviews have also been recently published on the subject. Special mention should be made of Memoirs published by the Indian Research Fund Association (Aykroyd, Krishnan, Passmore and Sundararajan 1940) and also of a booklet compiled and issued under the auspices of the F.A.O. (1954). The work done in India up to 1940 has been covered by Aykroyd *et al.* (1940) in their review. The present review, which may be considered to be a continuation of these earlier publications, is mainly concerned with describing the work carried out in India during recent years.

NUTRITIVE VALUE OF RICE

Chemical Composition. From the nutritional point of view, rice is predominantly a starchy food though it also contributes useful quantities of proteins and vitamins. The protein content (usually five to six per cent.) in the raw polished grain is lower than that of most other grains. The biological value of the protein as determined both by animal experiments and human metabolism studies is, however, shown to be of a high order and distinctly superior to that of wheat (Swaminathan 1937-38, Acharya, Niyogi and Patwardhan 1942, Mitra, Verma and Ahmad 1948 and Basu, Basak and De 1941). As compared with wheat which is itself deficient in calcium, rice contains a still lower percentage of this essential mineral. The commoner specimens of rice contain hardly ten mg. per cent. of calcium. Some varieties do contain more but the total quantity rarely exceeds 30 mg. per cent. The phosphorus content is also low and about 75 per cent. of it is in the form of relatively unavailable phytin (Giri 1938, 1940, Sundararajan 1938, Sathe, Venkita-

subramanian and De 1952). As regards the B-group vitamins, the hulled rice grain contains nearly as much as wheat, though the thiamine content is generally lower than in wheat. In the case of rice, the minerals and the B-group of vitamins are largely concentrated in the germ, the scutellum and the peripheral bran layers. This had been indicated by the work of Subrahmanyan, Sreenivasan and Das Gupta (1938) at the Indian Institute of Science, Bangalore, and that of Aykroyd (1932) at the Nutrition Research Laboratories, Coonoor. It was further quantitatively demonstrated by Nichols (1947), Hinton (1948) and Simpson (1951) by actual analysis of the various anatomical parts of the rice grain.

Loss of Nutrients during Milling. The concentration of the vitamins and the minerals in the surface layers and also, in the easily detachable germ leads to considerable loss of the nutrients during the milling of the grain. Rice is being milled often to the extent of 15 per cent. so as to ensure better keeping quality and to obtain an attractive product with good cooking quality. As a result of this, a substantial part of the essential minerals and vitamins are lost to the consumer. To avoid, at any rate, some part of this loss, undermilling has been repeatedly suggested especially for people whose main article of diet is rice. Home-pounded rice is undermilled and contains about 2γ thiamine/g. and its use wherever possible is to be advocated. The Baguio Nutrition Conference on Rice (1948) and the Nutrition Advisory Committee of the Indian Council of Medical Research have recommended the milling of rice to such a degree that it will still leave at least 1.8γ per g. of thiamine in the rice. This has been considered a safe level for the prevention of beriberi in people consuming rice diets.

Loss of Vitamins during Washing and Cooking. The wasteful effects of washing rice in large amounts of water, prior to cooking, and also the loss of nutrients as a result of discarding the gruel obtained by cooking the rice in excess water have been demonstrated. If these practices are followed, only about 25 per cent. of the vitamins present in the original grain has been shown to be retained by the cooked rice [Ranganathan, Sundararajan and Swaminathan (1937) and Swaminathan (1942)]. Parboiled rice has been demonstrated to behave better than raw rice in this respect because washing of this rice prior to cooking removes less vitamins than in the case of raw rice.

In most rice eating countries, the rice as purchased from the market is not completely free from bran residues, dirt, dust, etc. In practically every home, washing rice two or three times is practised as a regular procedure to remove these impurities. Even the very first washing will leach out a considerable amount of vitamins and minerals. A specific recommendation to reduce the number of washing will not, therefore, materially reduce the extent of loss of nutrients by washing. As far as possible, dirt and bran should be removed by winnowing and if washing has to be resorted to, the grain should not be rubbed under water as is usually done but the grain poured into the cooking water and the floating impurities removed by skimming out.

Similarly, the practice of cooking rice in excess water which results in loss of nutrients in the gruel has arisen out of necessity. If the gruel is left behind, the cooked rice is pasty. This is especially true in the case of freshly harvested rice, which

cooks to a very pasty mass which is difficult to digest. The gruel is usually discarded although in some poor homes it is used along with soup. Such gruel loss is more when the rice is cooked in a vessel directly over fire. The ebullition of the boiling water makes the grains hit against each other and starch is leached out into the cooking water and a thick sticky gruel will result. This difficulty is not experienced during the cooking of parboiled rice, because the parboiled grain is hard and leaching of starch into the cooking water is usually very little. The steam cooking of rice will reduce the above difficulties and should, therefore, be recommended. In this connection, it may be noted that the use of steam-cookers, especially by middle class families of average size, is increasingly coming into vogue.

Varietal Differences. Reference has been made by Aykroyd *et al.* (1940) to the varietal differences in nutritive value and the effect of cultural practices on the vitamin B_1 content of rice (McCarrison 1928). The general observation of Sadasivan and Sreenivasan (1938) was that the coarse and coloured varieties of rice which usually happen to be short-duration varieties have higher protein and mineral contents as compared with the fine-grained varieties. Data on the proximate composition and vitamin content of several varieties of rice have recently been collected by Kuppuswamy *et al.* and Chitra *et al.* (1955). Some varieties with thiamine content as high as 6γ/g. have been reported recently by Bannerjee and Guha (1955). It is desirable to develop by selection or by other plant breeding techniques, a fine or medium variety of rice with a protein content approximating that of wheat. It is pleasing to note that good work in this direction is already being done at the Rice Research Institute, Cuttack.

DETERMINATION OF THE NUTRITIVE VALUE OF RICE

The nutritive value of rice has been determined by many workers, chiefly on the basis of chemical analysis of proximate principles with special reference to total nitrogen, vitamins and minerals. The growth-promoting value of rice samples has been determined by feeding experiments with albino rats. Both chemical and biological assays are necessary to evaluate the nutritive value of a product. While the data on animal growth give an idea as to the overall nutritive value of the rice, the chemical analysis indicates the reasons for the nutritive value of a sample being high or low.

Experiments with Rats and Human Subjects. In addition to rat growth experiments, it is both desirable and necessary to conduct human feeding experiments to study the effect of various treatments on the nutritive value of rice. The growth rate of the rat is largely influenced by the level of calcium in the diet, whereas such a pronounced response to calcium may not be seen in the case of human subjects (Albanese 1950). The rat has also the capacity to utilize phytin phosphorus to some extent (Patwardhan 1937). It is, therefore, reasonable to expect that the response of the human subjects to different forms of treated or processed rice may not be of the same order as that of the rat though the latter would provide some useful basis to start on. A case in point is the effect of milling and undermilling on the nutritive value of rice. Rat growth experiments have shown a superiority in favour of unmilled and undermilled rice as against polished rice (Narayana Rao and Swami-

nathan 1953). In the case of the human being, metabolism studies have shown that the overall mineral and nitrogen balances are better with polished rice than with unpolished rice (Cullumbine *et al.* 1950 and Cullumbine 1950). The extent to which the human subject is able to utilize the coarse fractions of the bran would require further study. Here again, occupation and habits may be an additional factor in determining the efficiency of utilization. Since phytin phosphorus lowers the availability of dietary calcium to the human being (Walker 1948), the consumption of unpolished rice, which contains about 80 per cent. of its phosphorus in the form of phytin will have an unfavourable effect on the utilization of calcium in the rice-eaters' diet. This effect would be particularly striking if the diet is otherwise deficient in calcium as in the case of the ' poor ' rice diet of South India.

Need for more Extensive Human Metabolism Studies. There is evidence to show that the human being needs a period of adaptation in changing over from the consumption of an easily digestible polished rice to unmilled rice which has more fibre and offers greater resistance to digestion (Cullumbine *et al.* 1950 and Walker 1948). While polishing of rice may remove the fibre and phytin phosphorus, it also depletes the rice of its B-vitamins. While the latter process is undesirable, the removal of at least a part of the fibre and phytin may be nutritionally desirable. From these considerations, it would be necessary to feed rice milled to various degrees, to human beings, and from the data on thiamine content, the utilization of protein, ease of digestion, etc., determine the optimal degree of polishing which produces the most favourable overall utilization of all the nutrients. The problem would be similar to that of determining the nutritive value of bread prepared from high and low extraction wheat flours.

The importance of such a study, especially with the leading commercial varieties, as also selected varieties with high protein and vitamin contents cannot be overestimated. Rice, as already indicated, is the largest major constituent supplying nutrients in the rice eaters' diet. Hence, if a particular treatment or a particular manner of cooking or consumption of the cereal is shown to have even a slight advantage over the existing practices, that should be advocated because the total benefit accruing from such a practice, over a long period, would indeed be very great.

POPULARIZATION OF UNDERMILLED RICE AND ITS STORAGE QUALITY

Just as the consumption of parboiled rice which has many nutritional advantages over raw rice is to be advocated, so also the use of undermilled rice containing at least 1.5 γ/g. of thiamine has to be carefully considered, taking into account the various aspects like production, storage quality and consumer-acceptability of undermilled rice as against that of polished rice.

Consumer Acceptance of Undermilled Rice. The chief difficulty that has been recognized in the popularization of undermilled rice is its poor storage quality (Kik *et al.* 1945 and Narayana Rao *et al.* 1954) and its unattractive appearance which is objected to by the habitual users of white, polished rice. The experience in India has been that although the public have a preference for white polished rice, they can steadily accustom themselves to the use of undermilled rice provided (i) it is

offered at a cheaper rate and (ii) there is no ready and cheap facility for further mechanical polishing. The rice miller by himself is not averse to undermilling because he gets thereby a slightly greater yield of rice. If the Government, by legislation, bans overpolishing but permits undermilling, then there is a fair chance that the consumer may get accustomed to and even develop a taste for the undermilled product. The experience of the War years would however, show, that there is need for cautious approach. During the War and also the subsequent years of rationing, unpolished rice was sold to the public. As the organoleptic and cooking quality of wholly unpolished rice was very poor, the consumer found ways and means to polish—and often overpolish—the rice in an effort to remove the bad odour from rice, although polishing was not allowed by Law at that time. It is, therefore, desirable that the Government should advise all rice millers to produce rice of a specified and standardized degree of undermilling. It is at the same time necessary to ensure the consumers' acceptance of such a product.

Long Term Storage of Rice. The storage qualities of undermilled rice are intermediate between those of polished and unpolished rice. In view of the fact that, at present, the consumption of rice keeps pace with the production, the problem of storage of rice would not be a serious consideration. However, if the Government or other private agencies have to stock large quantities of rice for future exigencies which may arise through various causes, it would be advisable to store it in the form of paddy, and, failing that, as milled rice or parboiled rice. Storing of large buffer stocks in the form of unpolished rice is bound to result in considerable deterioration of the rice with the result that when such stocks are released at a later date, the public will have to overpolish it to remove at least a part of the bad smell. Long storage of undermilled rice may not also be desirable as it will attract insects and develop a rancid smell. Even undermilled parboiled rice will behave in a similar manner. Undermilled rice, however, resembles parboiled rice in some of its cooking qualities and people who are accustomed to it will not care for the very spongy cooking behaviour of white polishd rice.

Attention is being drawn to the above features of undermilled rice so that all the aspects may be taken into account when legislating for more extensive production of the product. Specifications have been already prepared for the degree of undermilling to be adopted, but it may not be possible to adhere to them quite rigorously. The same degree of polishing may not apply to all the varieties. The ideal thing will be to have a variety of rice that will be naturally quite rich in proteins and vitamins and which we can polish to a reasonable degree of whiteness. It is hoped that the scientists will soon find or evolve such a variety.

A special feature about rice is that it is used to a large extent in the form of a cooked whole grain, unlike most other cereals which are usually consumed after being made into flour. In fact, many of the nutritional defects in the customary practices of consuming the grain would not exist if rice could be consumed after being made into full extraction flour. The development of such diets is a far cry. As things stand, preparations made out of rice flour form only a small proportion of the dietary of rice-eaters. In this connection, special mention should be made of the leavened South Indian preparation popularly known as '*Idli*' which is made out

of blends of rice (generally parboiled) and decuticled black gram (*phaseolus radiatus* L.) which is a well-balanced and easily digestible product. It is pleasing to note that the popularity of '*Idli*' is steadily spreading to other parts of India.

DISCOLOURATION OF RICE DURING STORAGE AND ITS EFFECT ON NUTRITIVE VALUE

If paddy gets wet during the harvesting or threshing operation and is stored in godowns in a wet condition, a lot of heat is generated as a result of vital and microbial processes and the paddy acquires a dull colour. The rice from such paddy has a yellow or brown colour and such rice is called 'Zaphrani' in commerce in India. A very mild discolouration of the rice is actually preferred by the consumers as it is an indication of stored rice which is known for its better cooking qualities as compared with freshly harvested rice. However, if the discolouration is very pronounced it is a sign of improper storage and such discoloured rice is considered unhealthy as it is known to produce digestive disorders. It becomes bitter and more discoloured as the deterioration proceeds and beyond a certain stage, its organoleptic properties suffer. Recent reports from Japan indicated that certain types of samples may even prove to be toxic (F.A.O. report 1955).

Work has been carried out recently at the Central Food Technological Research Institute on the nutritive value of such discoloured rice as also on the mechanism of colour development. The physical and environmental factors conducive to the yellowing of the rice have also been studied. A variety of yellow rice obtained from a bulk godown was found to have deteriorated in its protein nutritional quality although its thiamine value remained unimpaired. No pathogenic strains of fungi or bacteria were found associated with the sample. Discolouration was also produced in polished rice in the laboratory and such rice was not found to have undergone deterioration in nutritive value although it had a pronounced fermented smell. However, advanced stage of yellowing or browning in rice is a sign of imperfect storage conditions and such discoloured samples have to be examined before being released for sale. In so far as hot and humid conditions of storage are conducive to the development of all types of microbes—both harmless and pathogenic—and as some metabolites arising as a result of fungal and microbial growth are known to be toxic, every effort should be made to improve the storage conditions in bulk godowns or warehouses. The paddy, to start with, should be well dried before storage and the ventilation in the godowns should be improved. The technological aspects of the design and construction of suitable types of driers and aerating equipment to reduce the moisture-content of wet, freshly-harvested paddy by at least 15 per cent. should be considered. In view of the proposals to establish buffer stocks of food grains all over the country, the problem needs immediate attention.

As already stated, samples of rice imported by Japan from some Far Eastern countries proved toxic (F.A.O. report 1955). The toxicity has been suspected to be due to its association with *Penicillium islandicum* Sopp., and *Penicillium citrinum* Thom., which produce toxic metabolites. These have not been isolated from the samples so far examined at this Institute but there exists a possibility that some varie-

ties of yellow rice in India may prove toxic, and there is need for finding out simple methods of distinguishing the harmless samples from the toxic type of yellow rice, without having to resort to microbiological identifications of the toxic species of microbes by tedious and time-consuming methods.

DEFICIENCIES OF THE 'POOR' RICE DIET

Diet surveys have shown that the diet of the habitual rice eater belonging to the low-income groups consists of 80 per cent. rice (Aykroyd 1948). In certain provinces, some amount of protective foods like fish, meat, millets, etc., are part of the poor man's diet and they exert a protective action, but the diet of the poor class in South India, particularly in the Madras State, contains very little of those foods that would supplement the deficiencies of rice. The poor South Indian rice diet, particularly the so-called ' Poor Madrasee Diet ' has become proverbial for its very low growth-promoting value as shown by extensive feeding experiments and the typically poor physical growth of the poor Madrasee. Following the earlier work of McCay (1912) and McCarrison (1932), Aykroyd and his co-workers have studied the nutritive value of such diets based exclusively on rice (Aykroyd *et al.* 1937 a & b.) The original typical composition of the poor rice diet was first proposed by Aykroyd *et al.* and was long used for rat growth experiments, but has been slightly modified since by the Vanaspati Research Committee (1953) to stimulate more nearly the diets actually consumed by human beings. Since, then, the results of many growth experiments based on this basal diet have been recorded with animals. The work has been recently reviewed by Moorjani and Subrahmanyan (1953) and Subrahmanyan, Kuppuswamy and Swaminathan (1954).

Two points have to be stressed in this connection. One is the variable growth response obtained by different workers with rats, although a similar type of diet is used. The reasons for such a variation may be due to difference in the variety of rice, its degree of milling, seasonal and environmental variations in growth response, etc., [Subrahmanyan, Kuppuswamy and Swaminathan (1954)]. In spite of these variations, the average growth promoting value of the typical Madrasee diet is generally not more than four to five gm. per week in the rat, whereas, on an adequate diet the increase in growth is of the order of 15 to 20 gm. per week. The poor rice diet as could be judged from its chemical composition is deficient in protein, vitamins and minerals. Calcium and iron are the deficient minerals. Vitamins A, B_1 and B_2 are also deficient in this diet (Patwardhan 1955 and Health Bulletin No. 23, 1951).

Need for Total Supplementation with all Nutrients. In growth studies with rats, it has been found that, among the single supplements calcium alone produces the maximum growth response. The average increase in weight with the typical poor diet can be increased in the case of the rat from four to six gm. to a value of nine to 12 gm. after supplementation with calcium salts (Moorjani *et al.* 1953). Other single supplements like protein, vitamins, etc., also produce some increased growth but this is very low as compared with that produced by calcium. Aykroyd and Krishnan (1937 b) have shown that addition of calcium leads to definite improvement in the case of human subjects. Further application of this finding in practical

human nutrition is to be considered. As the rice diet is a multi-deficient one, any practical programme of supplementation for the use of human beings must be composite one that will supply almost all the essential nutrients in which the typical rice diet is lacking. If a protein supplement is given, it should also be adequately fortified with vitamins and minerals. Mere vitamin supplementation without paying regard to protein and mineral deficiencies may not produce much benefit. While it is possible to supply deficiencies of vitamins and minerals by artificial enrichment with the synthetic vitamins or the purified mineral salts, the problem of protein supplementation is the more acute and a costly one, because proteins can be obtained only from natural sources.

SUPPLEMENTATION OF RICE DIETS

Milk. Milk in the form of whole milk, skim milk or dried skim milk powder is the ideal single supplement which will correct most of the deficiencies of the rice diet. This has been demonstrated in a number of experiments with animals as also by actual feeding experiments on growing up children in schools, hostels, etc., (Aykroyd *et al.* 1937 a.) There is scope for an increased production of milk and a better distribution of the available milk supplies. There is also need for introducing an efficient system of making the best utilization of imported skim milk powder so that it will reach the largest number of people who are in need of such supplements. The country cannot, however, depend always on imports. It has to fall back upon its own resources to meet the requirements of providing a cheap balanced diet to the entire population.

Fish. It has been indicated earlier that rice-eaters living in the coastal regions, especially in Bengal and on the South-Western Coast of India, consume fair amounts of fish. This item of food, although taken occasionally, will add useful amounts of protein, calcium and vitamins to the rice eater's diet (Basu and De 1938 and Basu, Basak and De 1942). The consumption of fish in larger amounts and, if possible, regularly, should be encouraged. The production and harvesting of fish both from inland rivers and marine sources is also being increased. The processing and preservation of fish by refrigeration, salt-curing, canning, etc., will also help in making fish available to areas away from the coast. Hydrolysates and concentrates prepared from factory waste would be a cheap protein concentrate, if it could be made edible.

Since the sources of protective foods of animal origin are meagre, balanced vegetable protein mixtures after suitable fortification with minerals and vitamins have to be used for supplementing the poor man's diet. The cost factor should also be considered in suggesting suitable supplements.

Pulses. Pulses are already being consumed as a part of the rice diet. The increased intake of the pulses would not only increase the total consumption of protein, but also make the protein more balanced nutritionally. The mutual supplementary action between the amino acids present in cereal and pulse proteins has been very clearly demonstrated (Swaminathan 1938, Phansalkar and Putwardhan 1956). Among these pulses Bengal gram (*Cicer arietinum*) has been found to have the highest growth-promoting value in rat growth studies (Acharya, Niyog.

and Patwardhan 1942), although other pulses like green gram (*Phaseolus mungo*), *thur dal* (*Cajanus cajan*), etc., are considered easy to digest. In fact, *thur dal* is the most common pulse consumed in the South, although green gram, black gram (*Phaseolus radiatus* L.), and Bengal gram are consumed in larger quantities in the North. Small quantities of other pulses like Field beans, (*Dolichos lablab*), horse gram (*Dolichos biflorus*), Cow pea (*Vigna catiang*), etc., are used wherever available.

Soyabean. The position which soyabean could occupy as a rich source of protein for supplementing the poor rice diet should be mentioned in this connection. Although soyabean contains about twice the amount of protein present in other indigenous pulses (I.R.F.A. Report on Soyabean 1944), it has not so for become popular in India as an article of diet. The reasons for this are two fold; first, it is not grown to a large extent in this country, and secondly, it has been found that in the form in which other pulses are used—in the form of a cooked *dal*—soyabean is very difficult to digest. This is particularly due to the fact that most varieties cannot be cooked to a soft consistency even after prolonged heating in boiling water. Consumed in the same quantities as other pulses, it proves heavy and difficult to digest because of its high protein content. It also contains bitter principles, tryptic inhibitors and other growth-retarding factors, which can be destroyed only after prolonged cooking (Ham *et al.* 1945 and Desikachar and De 1947).

Animal growth studies also do not reveal any superiority of soyabean (cooked) over other Indian pulses as a supplement to the rice diet, unlike what one would expect from its high content of protein, vitamins and minerals. The superiority of soyabean over other pulses can only be demonstrated if it is specially processed to destroy the growth-inhibitors and the bitter principles present in it. It is not clear as to how far the carbohydrates present in soyabean are interfering with the utilization of the protein. In rat growth studies, calcium was found to be the primary growth-factor limiting in the poor rice diet. It is only when the calcium deficiency in the diet is made up that the supplementary effect of the extra protein present in the soyabean is brought out (Desikachar and Subrahamanyan 1956).

The processing of the soyabean into an edible flour which can be used as part of the rice diet is, however, to be tried. In this form it is likely to be accepted by the rice eaters. The processing of the bean in the form of an emulsion has also been attempted and detailed studies about the nutritive value of the milk have also been carried out. The milk is free from undigestible matter and unlike the bean it is very easy to digest. Soya milk is however, deficient in calcium as compared with cow milk, and needs to be fortified with this mineral. The milk and curd, have a better nutritive value than the whole bean. These processed soya products play a very important role in the dietary of rice eaters in China and other Far-Eastern countries. So far, such products have not been readily accepted by the Indian public because of the characteristic nutty flavour of the milk, although its nutritional possibilities have been shown by extensive animal experiments and by growth and metabolic studies on human beings. The data obtained on the nutritive value of vegetable milks have been summarized recently in a publication of the Indian Council of Medical Research (1955).

Groundnut Milk and Curd. The possibilities of a similar milk and curd prepared from groundnut have been studied at the Central Food Technological Research Institute. The supplementary value of the processed curd has been studied both by rat and human feeding experiments. The curd has been in production for some years and is being increasingly used. If a ready off-take of the milk or curd is assured, production can be taken up at least in those centres where there is acute shortage of milk and milk products.

Edible Oilseed Cake Flours. As already indicated the oilseed cake flours are a rich source of protein containing 40 to 60 per cent. of crude protein. The amino acid composition of the oilseed proteins is now well known and suitable mixtures of these seed cake flours can correspond very nearly in nutritive value to that of first-class animal proteins. It is needless to say that if they are intended for human consumption they have to be specially processed under hygienic conditions so as to exclude dirt, grit, etc. In certain cases, the cuticle will have to be removed because it may either impart an objectionable colour or have a poor digestibility. The nutritional possibilities of such balanced mixtures (after adequate fortification with the necessary vitamins and minerals) as suitable supplements for correcting the deficiencies of the rice diet are indeed very great. The preparation of such suitable blends for supplementing the diets of poor people has been attempted by several laboratories in India.

Protein Rich Compositions. The Central Food Technological Research Institute, Mysore (Subrahmanyan *et al.* 1957), the Nutrition Research Laboratories, Coonoor (Gopalan and Ramalingaswamy 1955) and the Indian Institute of Science, Bangalore (Lal and De 1952 and Rajagopalan 1956), have evolved suitable blends of protein-rich food for supplementing the poor man's diet. The composition developed at the Central Food Technological Research Institute consists of a mixture of specially prepared white groundnut cake flour mixed with Bengal gram flour. It has been termed as the 'Indian Multipurpose Food' as it is intended for being used in the same way as the M.P.F. prepared from a soyabean base developed by the 'Meals for the Millions' Foundation of the United States. The product developed at the Central Food Technological Research Institute has been found to have a very good supplementary value to the poor rice diet. The production and popularization of this food has already found favour and it is expected that a factory for its production will soon be set up.

The above types of protein-rich foods when used in quantities of about two ounces per day will correct the deficiencies of the rice diet. Although they are primarily meant for general supplementation of poor diets, they would also be useful for combating disease, like *Kwashiorkor* resulting from protein malnutrition. Young and growing children, pregnant and nursing mothers and convalescents will also benefit from such protein-rich supplements as they also provide vitamins and essential minerals.

For those people who are not in a position to digest large quantities of protein and the fibre associated in these mixtures, pre-digested or partially digested preparations have to be produced. Preliminary digestion and extraction of the solubilized materials will eliminate the fibre from the mixtures.

Mysore Flour. The increased utilization of oilseed cake flours has also been attempted in other directions. As tubers are poor in protein, but are useful food crops by virtue of their relatively high yield per acre, mixtures of tuber flours with specially prepared oilseed cake flours would be nutritionally balanced mixtures. One such blend called the 'Mysore Flour' consists of a mixture of tapioca flour and groundnut cake flour and can be used in place of wheat flour. The nutritive value of this mixture has been demonstrated at the Central Food Technological Research Institute Mysore, by Murthy, Swaminathan and Subrahmanyan (1950) and Sur *et al.* (1954).

So far, only groundnut cake has been attempted to be used for human feeding. Other oilseed cake flours like cottonseed cake, sesame cake, etc., could also be used, but they would require a more elaborate processing for edible purposes. If solvent extraction can be adopted for removing the residual oil present in the expeller cake, the keeping quality of the cake flours can be very much enhanced and to that extent their usefulness as articles of human dietary could also be increased. The example of soyabean cake flour can be cited in this connection. After removal of oil by solvent extraction and after processing to remove the bitter principle and the proteolytic and growth-inhibitors present in it, the soyabean flour is a first class protein-rich source resembling skim milk powder. In taste and flavour it would resemble any other pulse flour commonly used in India. If groundnut cake and other oilseed cakes could be processed in a similar fashion, their popularization and increased consumption would definitely be easier.

Yeast. Although yeast is a rich source of protein, minerals and the B-vitamins and is shown to have a good supplementary value to the rice diet by rat feeding experiments (Sur, Reddy, Swaminathan and Subrahmanyan 1954), the inclusion of yeast in human diets has not been popular. This is chiefly due to the peculiar flavour associated with it and the difficulty experienced by some people in digesting more than very small quantities of it. Unless the flour is removed either by processing or by improving the strain of the yeast culture, it is not likely that people will accept it readily. Although it may not become popular as a general article of food, its use as a tonic under the category of a protein-rich supplement among convalescent patients could be encouraged.

Fortification of Rice. While parboiling is a method of conservation of the nutrients naturally present in rice, enrichment of the rice with synthetic vitamins and minerals will compensate their loss due to overpolishing. If conditions in India are considered, enrichment may prove costly, because synthetic vitamins have to be imported. As the rice mills are small and are dispersed, the production of the enriched rice and its mixing with the raw rice cannot easily be standardized and controlled. As parboiling is already a familiar process, the production of parboiled rice in larger amounts and under hygienic conditions should be encouraged. It is because of the wide-spread use of parboiled rice by the poor people that the incidence of beriberi is not so common in India as in other rice-eating countries.

Other Proprietary Tonic Foods. Such foods are not intended for general consumption as they are processed for special purposes. In view of their higher cost also, they would be unsuitable as general supplements to the poor rice eater's

diet. Most tonics used by convalescents at present belong to the category of medicinal and pharmaceutical preparations. If, however, these tonics are prepared in the form of natural foods which people are accustomed to consume as part of their food, they would be more readily acceptable to the convalescent patients. For instance, if the tonic food is in the form of a grain or flour, it can be cooked and eaten as rice or wheat flour. If a highly nutritious blend or mixture is compounded and then transformed to the shape of a rice grain which can be cooked in a short period, the tonic rice could serve as a daily food to those in need of extra nutrition. (Subrahmanyan *et al.* 1953).

CONCLUSION

The rice diet in India, as also in many other countries, is associated with dense population and low economic status of a large section of the people. Although there is yet no direct evidence to show that rice is, in any way, directly responsible for increased fertility among human subjects, there may be other indirect factors favouring high concentration of population in the big rice belts of the World. The low level of nutrition among rice eaters is no doubt, due, to some extent, to ignorance. Faulty diet habits exist among all the sections of the people both rich and poor and these have to be corrected by proper education in the field of nutrition. The chief cause of malnutrition is the inability of the large section of the population to buy the well-known nutritive and protective foods. These are either in a scant supply or are too dear to buy.

There is, to some extent, a scope for increasing the production of protective foods like milk, fish, fruits, etc., and efforts are being made to increase their output. The basic problem is economic, and it is of prime importance to suggest nutritive and balanced foods which are within the reach of the poor man, and it is here that the science of nutrition can help us. Newer knowledge in nutrition has shown that it is possible to blend available cheap foods in such a way that they become nutritionally balanced. It should, therefore, be the purpose and joint endeavour of scientists, technologists and social educationists to see that the benefits of proper nutrition should reach all the people. Improvement of the nutritional level of the rice eater should be attempted from all angles—spread of proper nutrition education, provision of cheap, nutritionally balanced mixtures as supplementary foods, increasing the production of protective foods and the most important of all, improving the overall economic status of the people so that they can afford to buy the foods they need to guard their health,

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CHAPTER 34

SUMMARY

About half of the world's arable land is under cereals, and about a one-fifth of the total cereals is under rice. But over 90 per cent. of the world's rice is grown in the area known as Far East or Monsoon Asia.

India occupies a unique position among the rice-producing countries growing as it does nearly 38.7 per cent. of the world (excluding U.S.S.R. and China) acreage, *viz.*, 74 million acres, and contributing 32 per cent. in respect of production, i.e. 36.3 million tons of paddy, valued at approximately 1,130 crores of rupees.

Within India itself, Bihar occupies the largest area, 17.4 per cent., West Bengal, Madhya Pradesh, Uttar Pradesh and Orissa come next with 12.13 per cent. each. Assam and Andhra, though important rice-growing areas, occupy only 5 per cent. each of the total Indian acreage. The remaining acreage is scattered in the other states of the Union. Excepting for 32 per cent. of the acreage which is irrigated, mainly in the Punjab, Andhra and Madras, the rest of the rice crop depends on the monsoon. Of the three rice crops usually raised in this country, *viz.*, winter, autumn and summer, the winter crop accounts for the maximum acreage and production.

Of the 7,000 botanical varieties of rice known in the world, four thousand have been identified in India. The variations in characteristics of these thousands of varieties are brought about by soil and climatic conditions and characteristics specific to a particular genetic type. However, all these thousands of varieties can be grouped from a commercial and marketing point of view into three classes, namely: (i) 'fine', 'medium' or 'bold', (ii) raw or parboiled and (iii) machine-milled or hand-pounded.

The total supply of rice of all the types and qualities mentioned amounted to about 26.9 million tons in 1955-56 which included 0.205 million tons imported, chiefly from Burma. As a result of increased production achieved under the national development schemes, there has been less dependence on imports which declined from 0.74 million tons in 1951-52 to 0.2 million tons in 1955-56, though in 1954-55 imports registered a slight increase over 1951-52. India's share in the export trade has been insignificant, and that too after the decontrol of rice in July 1954. The exports have been chiefly of fine and scented rices, the total exports not exceeding 1½ lakh tons during 1954-55 and 1955-56.

In the years following, imports have again gone up and during 1957, India imported 0·73 million tons of rice.

Nearly two-thirds of the annual rice production is retained by the producers for domestic consumption, barter sales, seeds and payments in kind, releasing only one-third, i.e., about 7.5 million tons for the market, valued approximately at Rs. 364 crores.

The producer's share in the assembling process, so far as rice crop is concerned, normally amounts to a little over 1/8th or 13 per cent. of the total market-

able surplus, owing to excessive deductions and malpractices in the market, and financial obligations to creditors who are merchants in the secondary and wholesale markets, and as a rule, interested in procuring his produce directly. Thus, the share of the producer in the rupee, paid by the consumer has been 50 to 60 per cent. In order that the cultivator's share in the assembling process as well as in the rupee paid by the consumer should increase, regulatory measures have to be employed. At present, so far as rice is concerned, markets are regulated in the Punjab and the former state of Hyderabad. The market charges payable on paddy and rice in these regulated markets are appreciably lower than in unregulated markets. In the states where an Act is in operation, it can be usefully extended to other markets and commodities such as paddy and rice. In areas like Assam, West Bengal, Bihar, Orissa and Uttar Pradesh where such legislation does not exist, steps are being taken to enact the necessary measures.

All the rice converted by milling is distributed mainly by wholesale merchants and rice mills. The growers, thus, play an insignificant part in distribution too.

Rice is the most important single item of food in India and more than 90 per cent. of the production is consumed in various cooked preparations, the bulk being taken in the form of plain boiled rice. The *per capita* consumtpion of rice varies widely, depending on the consuming habits and preferences of a locality. The highest *per capita* consumption of rice in India is 314 pounds in West Bengal. The next in order of consumption are Assam, Madras and Madhya Pradesh. The lowest is in Uttar Pradesh and the Punjab, being 74 and 20 pounds, respectively.

Of the three varieties of rice, i.e., 'fine,' 'medium' and 'bold (or coarse)', 'medium' rice is normally the most important commercially, as it constitutes nearly half of the total market requirements in India. 'Bold' (or coarse) rice is usually consumed by cultivators, artisans and manual workers though in periods of shortage, 'bold' rice has been consumed by all classes of people, and may be said to have assumed greater importance from the marketing point of view.

In India, there is no such thing as average price of rice. An examination of prices is handicapped by several factors such as existence of an enormous number of varieties, the complexities of consumer preferences, the localization of production types, the localized nature of demand, and the non-existence of any representative types or standards of quality. Due to the reasons detailed above, records of paddy prices are not available for a number of local centres, and when available, are frequently found to be biased.

In common with other agricultural products, the prices of rice and paddy are subject to well-defined seasonal fluctuations, which are greater in the case of paddy. Normally, rice prices in the country are depressed between December and May, and lowest generally in January, excepting in Madhya Pradesh and Assam, where prices are normally lowest in March and April, respectively. The periods on the whole synchronize with large arrivals after the harvest.

Rice prices in different markets normally show little or no tendency to move in close sympathy. Prices at consuming centres do not necessarily follow closely the market from where supplies are drawn, and may, in fact, show diametrically opposite tendencies. If the prices of raw and parboiled rice prepared from the same

variety of paddy are compared, it is found that parboiled rice is cheaper than raw rice, the difference being Re. 1 to Rs. 1-8-0 per maund in respect of 'fine' and 'medium' rice, and anything from 8 to 10 annas for the 'bold' category. 'Fine' and 'medium' hand-pounded rice is generally dearer than machine-milled rice. The premium on hand-pounded quality does not always apply to 'bold' rice.

In the case of paddy, price differences due to quality are based on: (i) Conformation or grain-size, (ii) milling quality, (iii) age (certain area only) and (iv) physical characteristics such as impurity content, proportion of damaged or defective grains, red grains, admixture of other varieties, and moisture content. As with rice, fine paddies are normally dearest and the 'bold' the cheapest, with 'medium' varieties falling between the two extremes. But the differences between 'fine' or 'medium' or 'bold' paddy are somewhat smaller than those of rice.

With a view to bringing about a standard system of classifying rices and establishing uniformity, measures have been taken under the Agricultural Produce (Grading and Marking) Act, 1937, to draw up standard grade specifications of rice. Under this scheme, each variety is covered by a separate schedule. For each variety, the limits of tolerance for admixture and defective diseased grains have been laid down, in addition to fixing the size, shape, etc., of the grain of each variety. When this scheme extends to all the rice-producing and marketing regions in India, it is hoped that a good measure of uniformity in the marketing of rice would be brought about, and this would, in turn, result in better returns to the cultivator.

Rice is stored in the villages mostly in the form of paddy, as the same keeps better and longer in that condition. The receptacles used for storing are made of plaited straw, split bamboo, mud or brick work or wooden receptacles. In some states, pits are used for storing paddy, and this pit system is common in Madras, some parts of Bihar, Orissa and Uttar Pradesh. In the markets, paddy and rice are stored in *kutcha* godowns with some sort of a covering either of straw or bamboo mats. At mills and ports, both paddy and rice are stored in bags. The storage costs vary from 5 to 6 pies per maund per month in the case of a *kutcha* godown to about 20 pies in the case of a *pukka* godown. The loss in storage either due to dampness, weevil attack, pest infestation, etc., is estimated at about one to two per cent. The total loss in storage of this crop either as paddy or rice is reckoned at 3,70,000 tons, annually. Of this, about 48 per cent. loss takes place in paddy storage, and the remainder in rice. On the whole, the position in respect of the storing of rice and paddy at the market, not only at the wholesale market level, but also at the rural level is extremely unsatisfactory.

Rice is handled by various agencies from the stage it is harvested to the stage it is brought to the markets. The operations at the village are carried out either by the cultivator himself or by hired labour. The cost of handling works out to 1 to 2 annas per maund at village level, annas 2 to 4 at market level, and an equal sum of money at rail heads, river heads or at ports. The movements of paddy and/or rice are carried out on head loads, pack animals, bullock carts, motor vehicles and by rail and waterways. Of the movements by rail, road, and waterways, the

cheapest is by that of the waterways. Road transport is now functioning at a very competitive rate with the Railways. However, there are certain typical instances, where this is not always the case. For example, in Kerala the cost of movement by rail and waterways is the same and is about Rs. 5 per ton per 40 miles.

The three principal rice products of any commercial importance in India are parched rice (*murmura*), beaten rice (*chura*) and parched paddy (*kheel*). Although the proportion is relatively small, the quantity of rice processed into the three products is fairly considerable, and as a cottage industry, provides employment for a large community known generally as *bharbhunjas*. The quantity of the above rice products manufactured in various states differs considerably, and to a large extent reflects the demand, the character of which is variable and fairly localised. No data are available to show the volume of trade in parched rice, parched paddy and beaten rice, but this is probably not more than ten per cent. of the total production, beaten rice occupying a more important position from the marketing viewpoint than the other two preparations. In so far as the prices are concerned, these are not maintained, nor are a series of quotations of fairly long periods available from the trade, but the relation between the prices of rice products and the raw material—rice or paddy from which they are made—is highly variable.

The secondary products of rice are mainly paddy husk, and rice bran which are by-products obtained in the process of rice hulling. The annual output of paddy husk in India may be estimated at an average of about ten million tons, a considerable portion of which is utilized as fuel in domestic cooking, for boilers in rice mills and also as a binder in mud plaster. Rice bran, the average annual production of which is roughly estimated to be about 1.6 million tons, should be of considerable commercial importance on account of the high nutritive quality as cattle feed, but is frequently disposed of mixed with paddy husk and its full value, is thus not always realised.

APPENDICES

APPENDIX 1

CLIMATIC CONDITIONS, RICE-GROWING SEASONS, CROPPING SYSTEM AND CULTURAL PRACTICES IN DIFFERENT STATES

Region, State and Latitude	*Rainfall*		*Temperature range* C°	*Crop season*	*Sowing time*
	Monsoon	*Average in mm.*		@	
1	2	3	4	5	6
1. NORTH-EAST REGION					
Assam	S.W.	2260-5892	16-35	*ahu* (A)	Apr.-June
22° to 29° N.				*sali* (W)	June-July
				boro (S)	Nov.-Dec.
West Bengal 22° to 26° N.	S.W.	1270-3759	16-35	*aus* (A)	Apr.-May
				aman (W)	June-July
				boro (S)	Nov.-Dec.
Orissa 18° to 21.5° N.	S.W.	1143-1778	17-35	*beali* (A)	Apr.-May
				sarrad (W)	June-July
				dalua (S)	Nov.-Dec.
South Bihar**					
2. SOUTHERN REGION					
Andhra 13.5° to 20°N.	S.W.	762	16-35	*sarava* (W) or *abi*	May-June
	N.E.	355		*dalua* or *tabi*	Dec.-Jan.
		1117			
Kerala 8° to 14°N.	S.W.	2286	27-32	*viruppu* (A)	April
				mundakan (W)	Sept.-Oct.
				punja (S)	Dec.-Jan.
Madras 8.5° to 13.5°N.	S.W.	1016	24-35	*kar* (A)	May-June
				samba (W)	June-July
				navarai (S)	Dec.-Jan.
3. WESTERN REGION					
Bombay 15.5° to 24°N.	S.W.	1270	16-32	Ist Crop (W)	May
Mysore**				2nd Crop (S)	Dec.
4. CENTRAL REGION					
Mysore 12° to 18°N.	S.W.	508-1524	16-32	*haine* (W)	June
				2nd Crop (S)	Jan.

Harvest time	Area in million acres	Average yield per acre in lb.	Cropping system	Cultural practices and remarks
7	8	9	10	11
Aug.-Sept. Nov.-Dec. April	1.00 3.19 0.02 4.21 (83)*	865	Single crop; generally followed by legumes. A small area double-cropped with rice or jute	Mostly rain fed and broadcast. Transplanting done in a small area. Floating rice grown in flooded areas
Aug.-Sept. Nov.-Dec. Mar.-April	1.59 8.90 0.04 10.53 (83)*	915	Single crop; generally followed by legumes. Double cropping with jute and rice in certain areas	Rain fed; second crop irrigated. Both broadcasting and transplanting followed
Aug.-Sept. Dec.-Jan. Mar.-April	1.31 8.17 0.03 9.51 (68)*	514	Single crop; generally followed by legumes. In certain areas double cropping of paddy is also practised	Mostly broadcast. Irrigation facilities for 20 per cent. of the area. Summer rice, jute and vegetable cultivation extending under irrigated conditions
Oct.-Nov. April-May	5.23 0.74 5.97 (24)*	1,005	Double-cropping of rice and growing of legumes commonly practised. In single crop areas with facilities for irrigation, sugarcane, vegetables, groundnut, and cotton are grown	Mostly transplanted. Irrigation facilities available for about 90 per cent. of the area. In Telengana area, broadcasting is commonly practised
Sept. Jan.-Feb. Mar.-April	1.00 0.65 0.17 1.82 (42)*	917	Single crop; generally double-cropping of rice and growing of tapioca, ginger and banana practised	Mostly broadcast; transplanting done for second crop. 20 per cent. area irrigated
Sept.-Oct. Dec.-Jan. April	3.70 1.08 0.08 4.86 (37)*	1,034	Double cropping of rice and growing of legumes is commonly practised. Sesamum, groundnut and sugarcane are grown in irrigated tracts	Mostly transplanted. Facilities for irrigation available for about 85 per cent. of the area
Oct.-Nov. March	3.79 0.15 3.94 (7)*	727	Single crop of rice followed by legumes in low lands	Transplanted or drilled, rain fed and irrigated
Dec. May	2.06 0.04 2.10 (9)*	940	Single crop; followed by legume; double cropping with rice and growing of sugarcane and sweet potato under irrigation	Transplanted and broadcast. Irrigation facilities available

APPENDIX 1—*Concluded*

1	2	3	4	5	6
Telengana (Andhra Pradesh)**					
Madhya Pradesh 18° to 26.5°N.	S.W.	1016-1524	8-46	*kharif* (W)	June
Bihar 22° to 27°N.	S.W.	1016	10-35	*aus* (A)	May-June
				aman (W)	June-July
				boro (S)	Dec.
5. NORTHERN REGION Uttar Pradesh 24° to 31°N.	S.W.	1143	13-32	*kharif* (W)	June-July
Punjab 28° to 32°N.	S.W.	762-1524	33-43	*kharif* (W)	June
Jammu & Kashmir 32° to 36°N.	S.W.	292	7-35	*kharif* (W)	April-May

*Figures in brackets give the percentage area under rice of the total cultivated area in the state.

**The southern area of Bihar State with high intensity of rice is contiguous to West Bengal in the North-eastern region. Telengana area of Andhra Pradesh has similar cultivation practices and growing conditions as in Mysore in the Central Region. South Kanara district of Mysore has conditions similar to coastal area of Bombay State in Western region.

@Letters in brackets give corresponding crop seasons; (A) =Autumn, (W) =Winter and (S) =Summer.

S.W.—South-west Monsoon; N.E.—North-east Monsoon.

7	8	9	10	11
Oct.-Nov.	9.39 (27)*	619	Mostly single crop ; legumes to some extent	Mostly broadcast and rain fed. Transplanted 10 to 15 per cent. under irrigation
Sept.-Oct. Nov.-Dec. Mar.-April	1.19 11.04 0.02 12.25 (50)*	528	Single crop ; followed by legumes in certain areas	Broadcast and transplanted. Mostly rain fed. A small area under irrigation
Nov.-Dec.	8.91 (22)*	514	Single crop ; rotated with legumes, peas or wheat. Intercropping with red gram	Rice grown mostly in the eastern area. Mainly rain fed and broadcast. 20 per cent. under irrigation, transplanted
Nov.	0.63 (4)*	790	Single crop ; followed by oil-seed or legume	Rice in hilly areas mostly rain fed and broadcast. In the plains, mostly irrigated and transplanted
Sept.	0.46(33)*	953	Single crop ; mostly followed by oilseeds or lentil in some areas	Crop grown in terraced lands. Mostly broadcast

APPENDIX II

LIST OF FUNGI RECORDED ON RICE IN INDIA

Pythium debaryanum Hesse
Rhizopus nigricans Ehr.
Monascus purpureus van Tieghem
Aspergillus oryzae (Ahlburg) Cohn
Cochliobolus miyabeanus (Ito & Kurib.) Drechsler ex Dastur=(*Helminthosporium oryzae* V.B. de Haan)
(Syn :—*Ophiobolus miyabeanus* Ito & Kuribayashi)
Chaetomium indicum Corda
Chaetomium brasiliense Bat & Pont
Chaetomium brasiliensis Bat & Pont
Leptosphaeria culmifraga (Fr.) Cesati & de Notaris
(Syn :—*Sphaeria culmifraga* Fries)
Leptosphaeria oryzina Sacc.
Leptosphaeria salvinii Cattaneo
(Syn :—*Helminthosporium sigmoideum* Cav.
Sclerotium oryzae Cattaneo)
Melanomma glumarum Miyake
Melanospora zamiae Corda
(Syn :—*Sphaeronema zamiae* Cattaneo)
Metasphaeria albescens Thumen
Mycosphaerella malinverniana (catt.) Miyake
Ophiobolus oryzae Miyake
Trematosphaerella oryzae (Mujake) Padwick
(Syn :—*Phaeosphaeria oryzae* Miyake
Phyllosticta oryzae Hori)
Balansia oryzae (Syd.) Naras & Thirum—(*Ephelis oryzae* H. Sydow)
Gibberella fujikuroi (Sawada) Wollenweber
(Syn :—*Lisea fujikuroi* Sawada
Fusarium moniliforme Sheld)
Nectria bolbophylli P. Hennings
Entyloma oryzae H. & P. Sydow
(Syn :—*Ectostroma oryzae* Sawada
Sclerotium phyllachoroides Hara)
Neovossia horrida (Takahashi) Padwick and Azmatulla Khan
(Syn :—*Tilletia horrida* Takahashi)
Phoma oryzae Cooke & Massee
(Syn :—*Phyllosticta oryzae* (Cooke & Massee) Miyake
Phyllosticta glumarum (Ell. & Tr.) Miyake
(Syn :—*Phoma glumarum* Ellis & Tracy)
Phyllosticta miurai Miyake

Pyrenochaeta oryzae Shirai ex Miyake
Cercospora oryzae Miyake
Curvularia lunata (Wakker) Boedijn
(Syn :—*Acrothecium lunatum* Wakker)
Helminthosporium sigmoideum Cav. var. *irregulare* Cralley & Tullis
Helminthosporium tetramera McKinney
Helicoceras nymphaearum Linder & Tullis
Nigrospora oryzae (B. & Br.) Petch
Nigrospora sphaerica (Sacc.) Mason
Piricularia oryzae Cav.
Sphacelia oryzae Massee
Trichoconis padwickii Ganguly
Ustilaginoidea virens (Cooke) Takahashi
(Syn :—*Ustilago virens* Cooke
Tilletia oryzae Patouillard
Ustilaginoidea oryzae (Pat.) Brefeld
Sphacelotheca virens (Cooke) Omori
Rhizoctonia microsclerotia Matz
(Syn :—*Rhizoctonia solani* 'B. strain' of Park & Bertus
Sclerotium sphaeroides Nakata
Sclerotium No. 2 of Sakurai)

APPENDIX IIIa

DISTRIBUTION AND IMPORTANCE OF RICE PESTS IN VARIOUS STATES IN INDIA

Name of the insect (Order and Family)	*Andaman & Nicobar* 1	*Andhra* 2	*Assam* 3	*Bihar* 4	*Bombay* 5	*Delhi* 6	*Himachal Pradesh* 7	*Kashmir* 8	*Kerala* 9	*Madhya Pradesh* 10	*Madras* 11	*Manipur* 12	*Mysore* 13	*Orissa* 14	*Punjab* 15	*Rajasthan* 16	*Uttar Pradesh* 17	*West Bengal* 18
Field Pests																		
ORTHOPTERA																		
Family: *Acridiidae*																		
1. Acrotylus humbertiana *S.*											m							
2. Chrotogonus Sp.										s	m					m		
3. Colemania sphenarioides *Bol.*					m						m							
4. Heteropternis respondens *W.*											m							
5. Hieroglyphus banian *Fb.*	m	s	m	m	s		m	m		s	s		m	s	s	s	m	m
6. Hieroglyphus furcifer *Sw.*											m			s				
7. Hieroglyphus nigrorepletus *Bo.*		m				s				s	m				m		m	
8. Hieroglyphus orizivorus *U.*											s							
9. Oxya velox *F.*		m									m		m	s		m	m	
10. Pyrgomorpha conica *O.*											m							
11. Acrida turrita *K.*											m					m	m	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
12. Aelopus affinis *B.*											m					m		
13. Aelopus tamulus *F.*											m					m		
Family: *Locustidae*																		
14. Locusta danica *L.*											m							
COLEOPTERA																		
Family: *Cetoniidae*																		
15. Oxycetonia albopunctata *F.*																	m	
Family: *Chrysemelidae*																		
16. Chetocnema coccipennis *B.*		m									m							
17. Haltica cyanea J.										m	m		m				m	
18. Hispa (Rhadinosa) lebongens *Wlk.*		m																
19. Hispa armigera Ol. (aenescens *Baly*).		s	s	s	m		m	m	s	s	m	s	m	s	s		m	s
20 Leptispa pygmaea *Baly*			m		m	s			m		m		s	m				
21. Oides affinis *Ja.*											m							
Family: *Curculionidae*																		
22. Athesapeuta oryzae *M.*											m							
23. Echinocnemus oryzae *M.*			s								s			m				
24. Myllocerus dentifer *F.*											m							
25. Tanymecus indicus *Fst.*																		m

APPENDIX III a—*Continued.*

	1	2			5	6	7	8	9	10	11	12	13	14	15	16	17	18
Family: *Dynastidae*																		
26. Phyllognathus dionysius *F.* ..									m		m							
Family: *Meloidae*																		
27. Mylabris phalerate *Pall.* ..				m														
28. Epicauta sp. ..											m							
29. Gnathospastoides rouxi *C.* ..											m							
30. Lytta ruficollis *O.* ..											m		m					
31. Lytta ten[illegible] *P.* ..										m	m		m					
Family: *Melolonthidae*																		
32. Melolonthid beetle ..											m							
Family: *Rutelidae*																		
33. Anomala varians, *Ol.* ..				m							m							
Family: *Scarabaeidae*																		
34. Scarabid Sp. ..		m									m							
LEPIDOPTERA																		
Family: *Arctiidae*																		
35. Amsacta lactinea *Cr.* ..				s														
Family: *Eupterotidae*																		
36. Nisaga simplex *W.* ..													s					
Family: *Hesperiidae* ..																		
37. Parnara colaca *M.* ..									m									
38. Parnara mathias *F.* ..		m	m		m			m	m	m	m		m	m			m	m

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Family: *Lymanıriidae*																		
39. Psalis (Dasychira) securis *H.* ..		m	m						m		m							
Family: *Noctuidae*																		
40. Cirphis albistigma *M.* ..		m							m		m			m				
41. Cirphis loreyi *D.* ..							m				m		m				m	
42. Cirphis micacea *H.* ..											m							
43. Cirphis unipuncta *H.* ..		s	s				m			m	m	s		s			m	m
44. Pelamia frugalis *F.* ..											m							
45. Prodenia litura *F.* ..										s	m							
46. Remigia frugalis *F.* ..									m		m							
47. Sesamia inferens *Wlk.* ..		m								m	s		m	m	m		m	
48. Spodoptera mauritia *Bo.* ..	s	s	s	m	s		m		s	s	s	s	m	s		s	m	s
Family: *Nymphalidae*																		
49. Melanitis ismene *C.*		m	m				m		m	m	m		m	m			m	m
Family: *Pyralidae*																		
50. Ancylolomia chrysographella *Koll.* ..																	m	
51. Chilo simplex *But.* ..									m		m			m				
52. Chilo zonellus *Sw.* ..				s							m			m				
53. Chilotraea infuscatellus, *Snell.* ..											s			m				
54. Chilotraea (Proceras) polychrysa *Meyr* ..									m					m				
55. Cnaphalocrocis medinalis *Guen.* ..		m			m				m		m		m	m				m

APPENDIX IIIa—*Concluded.*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
56. Diatraea venosata *W.* ..				s														m
57. Nymphula depunctalis *Gn.* ..	s	s	s	s	s				m	m	s	s	s	s			m	m
58. Scirpophaga innotata *Wlk.* ..									m		s			s	m			
59. Scirpophaga nivella *F.* ..									m		s							
60. Schoenobius incertulas *Wlk.* ..	s	s	s	s	s		m	m	s	s	s	s	s	s	m	m	s	s
DIPTERA																		
Family: *Agromyzidae*																		
61. Pseudonapomyza atra Miegn. ..		m																
Family: *Anthomyidae*																		
62. Atherigona exigua Stein. ..									m		m			m				
Family: *Cecidomyidae*																		
63. Pachydiplosis oryzae (*W.M.*) Mani ..	m	s	m	s	s			m	m	s	s		m	s			m	m
RHYNCHOTA																		
Family: *Achilidae*																		
64. Nysisia atrovenosa *L.* ..											m							
Family: *Aphididae*																		
65. Tetraneura hirsuta *B.*(T. ulmi *K.*) ..											m			m				
Family: *Coccidae*																		
66. Ripersia oryzae *Gr.* ..		m								m	s		m	m				m
Family: *Coreidae*																		
67. Leptocorisa acuta *Th.* ..		m				m				s	s		m	s			m	s
68. Leptocorisa varicornis *F.* ..		m	s	s		s	m	m	s	s	s			s	m		s	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Family: *Deltocephalidae*																		
69. Deltocephalus dorsalis *M.* ..											m							
Family: *Fulgoridae*																		
70. Erythroneura subrufa *M.* ..									m		m							
71. Nilaparvata lugens Stal. ..		s									s			m				
72. Nilaparvata oryzae *L.* ..		s									m			s			m	
73. Nilaparvata sordescens *M.* ..		m									m			m				
Family: *Jassidae*																		
74. Nephotettix apicalis *M.* ..					m						m			m			m	
75. Nephotettix bipunctatus *F.* ..		m	m	m	m				m	s	m		m	m			m	m
76. Tettigoniella spectra *D.* ..		m	m		m				m	s	m							
Family: *Peutatomidae*																		
77. Menida histrio *Fb.* ..									m		m							
78. Nezara viridula *L.* ..											m							
79. Scotinophara lurida *B.* ..											s							
80. Tetroda histeroides *Fb.* ..											s							
THYSANOPTERA																		
Family: *Thripidae*																		
81 Thrips oryzae Will. ..		m	m						m		m		m	m				

S—serious pest

M—minor pest

APPENDIX IIIb

LIST OF STORAGE PESTS AND NON-INSECT PESTS ON RICE IN INDIA

Storage pests (Insects)

COLEOPTERA

Family: *Bostrychidae*

1. Rhizopertha dominica *Fab.*

Family: *Cucujidae*

2. Laemophloeus minutus *Ol.*
3. Oryzaephilus surinamensis *Li.*

Family: *Curculionidae*

4. Sitophilus grauaria *Li.*
5. Sitophilus oryzae *Li.*

Family: *Dermestidae*

6. Trogoderma granarium *Ever.*

Family: *Temnochilidae*

7. Tenebrioides mauritanicus *Li.*

Family: *Tenebrionidae*

8. Tenebrio molitor *Li.*
9. Tribolium castaneum *Herb.*

LEPIDOPTERA

Family: *Gelechiidae*

Non-insect pests (Crabs, Snails and Rats)

Phylum: *Arthropoda*

Class: *Crustacea* (Sub-class: *Entomostraca*)

Order: *Decapoda* (Section: *Brachyura*)

Family: *Telphasidae*

1. Gecarcinucus (Gecarcinucus) jaccuemontii *M.E.*
2. Paratelphusa (Barytelphusa) guerinf *M.E.*
3. Paratelphusa (Barytelphusa) jaccuemontii *Rathb.*
4. Paratelphusa hydrodromus *H.*
5. Paratelphusa (Paratelphusa) spinigera
6. Paratelphusa sexpunctatum *L.*

Phylum: *Mollusca*

Class: *Gastropods*

Order: Euthyneura (Sub-order: Pulmonata)

Family: *Limnaeidae*

1. Indoplanorbis exustus *D.*
2. Limnae acuminata *L.*
3. Pila virens *L.*
4. Viviparus variatus *F.*

10. Sitotroga cerealella *Ol.*	Class: *Mammalia*
Family: *Pyralidae*	Order: *Rodentia* (sub-order: *Simplicidentata*)
11. Corcyra cephalonica *St.*	Family: *Muridae*
12. Ephestia cautella *W.*	1. Bandicota bengalensis *G & H.*
	2. Gunomys kok *G.*
	3. Millardia meltada *G.*
	4. Rattus brevicaudatus
	5. Rattus rattus *Bl.*
	6. Tatera cuvieri *W.*

APPENDIX IV

IMPROVED RICE STRAINS OF INDIA

Sl. No. 1	*Strains* 2	*Origin* 3	*Agricultural group* 4	*Total duration (days)* 5
	ANDHRA			
1.	*Mtu. 1*	Sel. *Akkulu*	Winter	170
2.	*Mtu. 2*	,,	,,	170
3.	*Mtu. 3*	Sel. *Basangi*	,,	140
4.	*Mtu. 4*	,,	,,	145
5.	*Mtu. 5*	Sel. *Krishnakatukulu*	,,	170
6.	*Mtu. 6*	Sel. *Atragada*	,,	170
7.	*Mtu. 7*	Sel. *Guttikusma*	,,	180
8.	*Mtu. 8*	Sel. *Vankisannam*	,,	180
9.	*Mtu. 9*	Sel. *Garikasannavari*	Spring	120
10.	*Mtu. 10*	Sel. *Krishnakatukulu*	Winter	170
11.	*Mtu. 11*	Sel. *Konamani*	,,	170
12.	*Mtu. 12*	Sel. *Pedha Atragaaa*	,,	180
13.	*Mtu. 13*	Sel. *Delhibhogam*	,,	180
14.	*Mtu. 14*	Sel. *Atragada*	,,	170
15.	*Mtu. 15*	Hyb. (*Gariksannavari* × *Nallarlu*)	Spring	130
16.	*Mtu. 16*	Hyb. (*Konamani* × *floating type from Burma*)	Winter	170
17.	*Mtu. 17*	Sel. *Kodibudama*	*sarva*	
18.	*Mtu. 18*	Sel. *Kodijillama*	,,	
19.	*Mtu. 19*	Extracted from Nat. cross in *GEB.-24*	,,	
20.	*Mtu. 20*	Mutant		Early
21.	*Mtu. 21*	Pure line		

Sowing time 6	*Harvest time* 7	*Rice colour* 8	*Paddy yield lb./A* 9	*Remarks* 10
May-June	Nov. end	White	2,800 to 3,700	Cosmopolitan variety
,,	,,	,,	2,800 to 3,500	Suited to rich soil
,,	Late Oct.	,,	3,000 to 4,500	Stiff straw
,,	Oct. end	,,	3,000 to 4,000	Stands indifferent water supply
,,	Nov. end	,,	2,800 to 3,400	Delta variety, good tillering and uniform yield
,,	,,	Dull white	2,800 to 3,000	Suitable to low-lying areas
,,	Mid-Dec.	White	3,500	Stiff, non-lodging and non-shedding
	,,	,,	2,800	Stands indifferent water supply
Dec.-Jan.	April end	,,	3,000	Early shedding
May-June	Nov. end	Dull white	2,800 to 3,200	Fine, short-growing, non-lodging ; suited to rich lands
,,	,,	Brownish	3,000	Stands submersion and indifferent water supply
,,	Mid-Dec.	White	3,200	Easily shedding
,,	,,	,,	2,800	Good quality fine rice
,,	Nov. end	Brownish	3,200	Non-lodging
Dec.-Jan.	Early May	White	3,500	Less shedding than *Mtu. 9*
May-June	Early Dec.	Brownish		Suited to water-logged condition
May-June	Mid-Oct.	Red	1,500	Suited for rain-fed condition
,,	Oct. end	,,	1,500	,,
,,	Early Dec.	White	3,630	Non-lodging
		,,	3,200	Suited for 1st and 2nd crop
June	Dec.	,,		

APPENDIX IV—*Continued*

1	2	3	4	5
21a.	*Mtu. 22*	,,		
22.	*Slo. 1*	Sel. *Punasakonamani*	*sarva*	170
23.	*Slo. 2*	,,	,,	
24.	*Slo. 3*	Sel. *Konamani*	,,	
25.	*Slo. 4*	Sel. *Konamani*	,,	175
26.	*Slo. 5*	Sel. *Palagummasari*	,,	
27.	*Slo. 6*	Sel. *Punasa Akkullu*	,,	
28.	*Slo. 7*	Sel. *Bonthabasangi*	,,	
29.	*Slo. 8*	Sel. *Sannabasangi*	,,	
30.	*Slo. 9*	Sel. *Gorti Rasangi*	,,	
31.	*Slo. 10*	Sel. *Ratnachudi*	,,	
32.	*Slo. 11*	Sel. *Bikirismnnam*	,,	180
33.	*Slo. 12*	Sel. *Thellagarika sannavari*	*dalua* (spring).	120
34.	*Slo. 13*	Sel. *Punasa Akkullu*	*Sarva*	Medium
35.	*Slo. 14*	,,	,,	
36.	*Slo. 15*	Sel. *Konamani*	,,	180
37.	*Slo. 16*	Sel. *Kasipichoody*	,,	
38.	*Slo. 17*	Nat. cross in *GEB. 24*	,,	
39.	*Slo. 18*	Hyb. Nat. cross in *GEB. 24*	,,	
40.	*Slo. 19*	Hybrid		110
41.	*AKP. 1*	Sel. *Bobbiliganti*	*kar*	
42.	*AKP. 2*	Sel. *Sankisannam*	Winter	
43.	*AKP. 3*	Sel. *Gunpursannam*	,,	
44.	*AKP. 4*	Sel. *Mypali*	,,	160
45.	*AKP. 5*	Sel. *Mypali*	,,	
46.	*AKP. 6*	,,	*kar*	
47.	*AKP. 7*	Sel. *Palgarabayyahunda*	Winter	1C0
48.	*AKP. 8*		*kar*	
49.	*AKP. 9*	Sel. *Bangaru theega*	Winter	160

6	7	8	9	10
May	Early Dec.			Suited for low level areas
May-June	Late Nov.	White	3,150	Suited for clay soil
,,	,,	,,	3,500	
,,	Nov. end	,,		
,,	,,	,,	4,100	
,,	Late Nov.	,,	3,200	Coarse grain
,,	,,	,,	3,100	
,,	Late Oct.	,,	3,000	
,,	,,	,,	2,800	
May-June	Late Oct.	,,		Coarse
,,	Early Dec.	,,	2,800	Fine quality
,,	,,	,,	3,300	
January		,,	2,200	
May-June	Late Nov.	,,	4,100	
,,	,,	,,	3,900	
,,	Early Dec.	,,	4,100	Suited for heavy soils
,,	Late Sept.	,,	1,800	
,,	Late Nov.	,,	4,300	
,,	Early Dec.	,,	4,000	
			2,880	
June	Late Nov.	,,	2,200	Suited to high level land
,,	,,	,,	2,600	Fine variety ; resists drought
,,	Mid. Dec.	,,	2,500	Non-lodging, used as table rice
June-July	Mid. Dec.	,,	2,500	Fine rice of good quality
June-July	Mid. Dec.	Light red	2,900	
June	,,	White	3,100	
June	Early Dec.	,,	2,800	Coarse, suited to all types of soil
June	Late Dec.	,,	2,800	Fine, good quality rice suited to rich low-lying lands
June-July	Mid-Dec.	,,	2,500	Strong growing, non-lodging

APPENDIX IV—*Continued*

1	2	3	4	5
50.	*AKP. 10*	"	"	
51.	*AKP. 11*	Sel. *Ramasagaram*	*kar*	
52.	*AKP. 12*			
53.	*BCP. 1*	Pure line sel.		Long
54.	*BCP. 2*	"		
55.	*BCP. 3*	"		
56.	*BCP. 4*	"		
57.	*BCP. 5*	"		
58.	*Pla. 1*	Hybrid		
	ASSAM			
1.	*D. 204-1*	Sel. *Dumai*	*ahu* summer & autumn (B. cast & trans.)	80
2.	*M. 142*	Sel. *Koimurali*	"	93
3.	*C. 203-3*	Sel. *Chengri*	"	92
4.	*AS. 2*	Sel. *Kasalath*	*ahu* Trans.	110
5.	*AS. 3*	Sel. *Basmati*	"	122
6.	*AS. 24-1*	Sel. *Basanat Bahar*	"	102
7.	*AS. 86*	Sel. *Rangaduria*	"	100
8.	*AS. 48*	Se. *Dubaichanga*	*ahu* B. cast	103
9.	*ASC. 313-11*	Hybrid (*Rangaduria* × *Dacca No. 6*)	"	100
10.	*Ar. 1*	Sel. *Salibadal*	winter (bao)	226
11.	*Ar. C. 353-148*	Hybrid	"	214
12.	*Ar. C. 614-25b*	Hybrid	"	220
13.	*E.B. 1*	Sel. *Negheri*	winter (bao)	
14.	*E.B. 2*	Sel. *Kolongi*	"	
15.	*S. 155*	Sel. *Badshahbhog*	*sali*	170
16.	*Sc. 1177-6*	Hybrid	"	160
17.	*Sc. 94-47*	Hybrid	"	167

6	7	8	9	10
,,	Late Dec.	,,	2,800	
June	Mid-Dec.	,,	3,200	
		White	2,500	More resistant to blast
			2,700	Drought-resistant, blast-resistant
		White	3,000	Robust variety
		,,	3,200	Good quality, robust bunched head, non-lodging
		,,	3,000	Robust, bunched ear-head, draught resistant
		,,	2,800	Bunched head, suitable for 2nd crop, slightly drought-resistant
March-April	June-July	Red	1,640	Medium grains
,,	,,	,,	1,886	,,
,,	,,	,,	1,968	,,
April-May	Aug.-Sept.	,,	2,132	,,
,,	,,	White	2,080	,,
,,	,,	Red	1,840	Fine grains
,,	,,	,,	1,968	Medium grains
March-April	June-July	,,	2,132	,,
,,	,,	White	1,640	,,
,,	Nov.-Dec.	,,	3,526	Coarse, stands 2′ to 6′ water
,,	,,	,,	3,444	,,
,,	,,	,,	3,690	,,
				Stands 10′ to 15′ water
				Stands 8′ to 10′ water
June-July	Nov.-Dec.	White	2,624	Fine Scented
,,	,,	,,	3,444	Non-lodging
,,	,,	,,	3,444	Medium grains

APPENDIX IV—*Continued*

1	2	3	4	5
18.	*Sc. 412-56*	Hybrid	,,	168
19.	*S. 22*	Sel. *Lati Sali*	,,	165
20.	*S. 61*	Sel. *Prasadbhog*	,,	157
21.	*S.L. 70*	Sel. *Ahom Sali*	,,	162
22.	*S. 126*	Sel. *Laudunra*	,,	165
23.	*S. 36*	Sel. *Hati Sali*	,,	163
24.	*S.B. 279*	Sel. *Gomiri bora*	,,	
25.	*S.L. 240*	Sel. *Johori*	,,	162
26.	*Boro I*		*boro* (spring)	
27.	*Boro II*		,,	
28.	*Boro IV*		,,	
29.	*Boro V*		,,	
	BIHAR			
1.	*BR. 3 (115.B.K.)*	Sel. *Dahia*	Early *aman* (*katika*)	160
2.	*BR. 4 (141.B.K.)*	Sel. *Jhulansar*	,,	150
3.	*BR. 5 (16.B.K.)*	Sel. *Motisal*	Medium *aman* (early *agahani*)	170
4.	*BR. 6 (88. B.K.)*	Sel. *Dahia*	,,	170
5.	*BR. 7 (36. B.K.)*	Sel. *Kessore*	Late *agahani*	185
6.	*BR. 8(498-2A)*	,,	,,	190
7.	*BR. 19*	Sel. *Sona*		101
8.	*BR. 21*	Sel. *Sathika*		101
9.	*BR. 22*	Sel. *Deoghar*		95
10.	*BR. 1*	Sel. *Kolaba*		112
11.	*BR. 14*			
12.	*BR. 15*			
13.	*Purple hybrid*	Hybrid		
14.	*Purple hybrid*	Hybrid		
	BOMBAY			
1.	*Kolamba 184*	Sel. *Kolamba*	Autumn	105—110
2.	*Zinya 31*	Hyb.(*K.540* × *Z.149*)	Winter	125—130

6	7	8	9	10
»	»	»	3,362	Coarse grains
»	»	»	3,280	Coarse, non-shedding
»	»	»	3,280	Medium grains
»	»	»	3,280	»
»	»	»	3,280	Coarse grains
»	»	»	2,870	»
»	»	»	2,870	Glutinous
»	»		1,870	
Nov.-Dec.	April-May	Red	2,050	
»	»	White	2,400	Coarse grains
»	»	Red	2,000	
»	»	White	2,000	Medium grains
End June	End Nov.	White		
»	Last Nov.	»		
»	Early Dec.	Light red		
»	»	»		
»	»	White		
»	»	»		Resistant to lodging and diseases
		Red		For double-cropping, coarse
		»		»
		»		Spikelets enclosed within sheath
		White		Fine
Early June	Last Sept.	White	1,870	Fine
»	Mid-Oct.	»	2,400	»

APPENDIX IV—*Continued*

1	2	3	4	5
3.	*Kolamba 540*	Sel. *Kolamba*	Early winter	132—135
4.	*Kolamba 42*	Sel. *Kolamba*	Winter	145—150
5.	*Zinya 149*	Sel. *Zinva*	,,	145—150
6.	*Bhadas 12-11*	Sel. *Bhadas*		130—135
7.	*Kada 68-1*	Sel. *Kada*		115—120
8.	*Krishnasal—1*	Sel. *Krishnasal*		120—130
9.	*Patni 6*	Sel. *Patni*	Autumn	100—105
10.	*Panvel 61*	Sel. *Panvel*	Early winter	122—125
11.	*Bhadas 79*	Sel. *Bhadas*	Winter	135—139
12.	*Waksal 207*	Sel. *Waksal*	Early winter	120—125
13.	*Warangal 487*	Sel. *Warangal*	Winter	145—148
14.	*Maskaty 1315*	Sel. *Maskaty*	,,	124
15.	*Jaddu 1061*	Sel. *Jaddu*	Winter	134
16.	*Halga red 244*	Sel. *Halga*	,,	144
17.	*Halga white 1690*	Sel. *Halga*	,,	165
18.	*Mugad 161*	Sel. *Mugad*	,,	111
19.	*Mugad 81*	Sel. *Mugad*	,,	146
20.	*Mugad 249*	Sel. *Mugad*	,,	148
21.	*Mugad 141*	Sel. *Mugad*	,,	155
22.	*Antarsal 67*	Sel. *Antarsal*	,,	156
23.	*Antarsal 90*	Sel. *Antarsal*	,,	147
24.	*Antarsal 200*	Sel. *Antarsal*	,,	142
25.	*Waner*	Sel. *Waner*		120—125
26.	*Yalkirisal 4*	Sel. *Yalkirisal*		160—165
27.	*Dodgya 622*	Sel. *Dodgya*		125—130
28.	*Ambemohar 157*	Sel. *Ambemohar*		150—155
29.	*Ambemohar 159*	Sel. *Ambemohar*		150—155
30.	*Kada 176-12*	Sel. *Kada*		110
31.	*Early Kolam 161-62*	Sel. *Kolam*		95—100
32.	*Sukhvel 20*	Sel. *Sukhvel*		114
33.	*Kamod 118*	Sel. *Kamod*		128

6	7	8	9	10
,,	Late Oct.	,,	2,350	,,
,,	Early Nov.	,,	2,800	
,,	,,	,,	2,600	Very fine
,,	Late Oct.	,,	2,850	Bold
,,	Early Oct.	,,	2,500	
,,	Mid-Oct.	,,	2,300	Mid-fine, scented
,,	Late Sept.	,,	1,700	Coarse, resistant to the store moth
,,	Mid-Oct.	,,	2,000	
,,	Last Oct.	,,	2,200	Stiff-strawed
,,	Mid-Oct.	,,	2,000	Coarse
,,		,,	2,300	
End May	Early Oct.	,,	1,400	
	Mid-Oct.	Red	1,500	
	Early Nov.	,,	1,980	
	Last Nov.	White	1,890	
Early June		,,	2,484	Coarse
,,	Mid-Nov.	,,	2,514	,,
,,	,,	,,	2,379	,,
,,	Late Nov.	,,	2,728	
,,	,,	,,	2,589	
,,	Mid-Nov.	,,	2,484	
,,	,,	,,	2,556	
,,	Mid-Oct.	,,	1,700	Drought-resistant
,,	Last Nov.	,,	3,140	Fine
,,	Early Oct.	,,	2,000	Coarse, drought-resistant
,,	Late Nov.	,,	1,700	Fine, scented
,,	,,	,,	1,770	,,
Mid-June	Mid-Oct.	,,	2,676	Long, coarse
,,	Late Sept.	,,	1,531	Fine, long
,,	Early Oct.	,,	2,795	Mid-coarse, dwarf
Late June	Late Oct.	,,	3,041	Mid-fine, scented

APPENDIX IV—*Continued*

1	2	3	4	5
34.	*Pankhali 203*	Sel. *Pankhali*		127
35.	*Early Sutarsal 39*	Sel. *Sutarsal*		117
36.	*Late Kolipi 248*	Sel. *Kolipi*		145—150
37.	*Early Kolipi 70*	Sel. *Kolipi*		110—115
38.	*Early Ambemohar 102*	Sel. *Ambemohar*		135—140
39.	*Bhadas 1303*	Sel. *Bhadas*		135—140
40.	*Mahadi 4-4*	Sel. *Mahadi*		115—120
41.	*Garvel 1—8*	Sel. *Garvel*		150—152
42.	*Kala Rata 1—24*	Sel. *Kalarata*		120—125
43.	*Bhura Rata 4—10*	Sel. *Bhurarata*		110—115
44.	*Sannamaliga 79*	Sel. *Sannamaliga*		
45.	*Chimansal—39*	Sel. *Chimansal*		
	HYDERABAD			
	(Andhra Pradesh)			
1.	*RDR. 7*	Sel. *Rajagarkal*		102—105
2.	*RDR. 2*	Off-type *Rajagarkal*		120—125
3.	*HR. 19*	Sel. *Amritsari*		120—125
4.	*HR. 8*	Sel. *Gandharniku*	Autumn	125—130
5.	*HR. 67*	Sel. *Pichodi*		125—130
6.	*HR. 5*	Sel. *Palasannal*		130—135
7.	*HR. 12*	Sel. *Rajahansa*	Spring Autumn	120—135
8.	*HR. 21*	Sel. *Mahboob nagar Gowdalu*	Autumn Spring	135
9.	*HR. 22*	Sel. *Amritsari*	Autumn Spring	135
10.	*HR. 33*	Sel. *Dharmabad local*		135
11.	*HR. 47*	Sel. *Sukhdas*		135
12.	*HR. 1*	Sel. *American*	Winter	155—160
13.	*RDR. 4*	Sel. *Akkulur*		160—165
14.	*HR. 35*	Sel. *Kichidi Sannal*	Winter	170—180
15.	*HR. 38*	Sel. *Gutti Kusuma*	,,	185—190

6	7	8	9	10
Late June	Late Oct.	White	3,078	Fine, scented
Mid-June	Early Oct.	,,	3,022	Medium coarse
Early June	Early Nov.	,,	1,700	
,,	Early Oct.	,,	1,300	Fine
,,	Early Nov.	,,	1,460	Long, fine, slightly scented
,,	Late Oct.	,,	3,100	
,,	,,	Red	1,600	Coarse
,,	Mid-Nov.	White	2,450	Resistant to lodging
Mid-June	Late Oct.	Red	1,250	Coarse, salt-resistant
,,	Mid-Oct.	,,	1,250	,,
Late May	Last Oct.	White	2,421	Medium
		White	2,200	Medium fine
		,,	2,600	Medium
		,,	2,600	,,
June	September	,,	2,500	Coarse
		,,	2,600	Medium fine
		,,	2,500	Medium
Dec.-June	March-Sept.	,,	2,500	,,
June Dec.-Jan.	Sept.-April	White	2,200	Non-lodging, fine
June-July Dec.-Jan.	Oct. Mar.-Apr.	,,	2,000	Fine, scented
		Red	2,500	Coarse
		White	2,000	Fine, scented
June	Oct.-Nov.	,,	2,000	Resistant to blast and *Helminthosporium*
		,,	3,000	Coarse
June	November	,,	3,000	Fine
,,	,,	,,	2,800	Coarse, fairly resistant to the gall fly

APPENDIX IV—*Continued*

1	2	3	4	5
16.	*HR. 39*	Sel. *Gutti Kusuma*		185—190
17.	*HR. 59*	Sel. *Kaki Rekhalu*		185—190
	KERALA			
1.	*MO. 1*	Selection from *Chettivirippu*		85—90
2.	*MO. 2*	Selection from *Kallada Samba*		85—95
3.	*Cochin. 1*			130
4.	*Adr. 10*	Selection from *Cheriya Chutiiyaran*	First crop season (*viruppu*)	
5.	*Adr. 13*	Selection from *Karutha Chuttiyaran*	,,	
6.	*Adr. 14*	,,	,,	
7.	*Adr. 23*	Selection from *Valia vella*	,,	
8.	*Adr. 26*	,,	,,	
9.	*Adr. 36*	Selection from *Kochuvithur*	,,	
10.	*Adr. 67*	Selection from *Athikira-zihimundakan*	Second crop season (*mundakan*)	
11.	*Adr. 41*	Selection from *Karutha mundakan*	,,	
12.	*Adr. 52*	Selection from *Samba*	,,	
13.	*Adr. 74*	Selection from *Cheradi*	,,	
14.	*LUR. 19*	Selection from *Champa*	,,	150
	MADHYA PRADESH			
1.	*R. 2. Nungi No. 17*	Sel. *Nungi*	Autumn	Early
2.	*R. 3. Sultu gurmatia*	Sel. *Sultu gurmatia*	,,	,,
3.	*R. 4. Surmatia*	Sel. *Surmatia*	,,	Med.
4.	*Bhondu* × *Parewa* No. *116* on *22*	Hyb. (*Bhondu* × *Parewa*)		,,
5.	*Budhiabako* × *Lucha No 4*	Hyb. (*Budhiabako* × *Luchai*)		Late
6.	*Ajan* × *Lichai No. 4*	Hyb. (*Ajan* × *Luchai*)		,,
7.	*R. 8. Luchai*	Sel. *Luchai*	Autumn	,,

6	7	8	9	10
		,,	2,800	Coarse, resistant to blast and *Helminthosporium*
		,,	2,500	Fine, scented
Mid-Oct. Mid-Nov.	Mid-Jan. Mid-Feb.	Red	2,000—2,500	Coarse ; curved grains
Mid-Oct. Mid-Nov.	Mid-Jan. Mid-Feb.	Red	2,400—2,800	Coarse and awnless
September		Red	2,200	
April	Early August			Grown in *kumbhom* and *punja* seasons also
,,	Mid-August			,,
,,	,,			,,
,,	Early August			,,
,,	,,			,,
,,	Late July			,,
August	Early Jan.			Season fixed
,,	,,			,,
,,	Late Jan.			,,
,,	Early Feb.			,,
,,	,,	Red		Medium grain
Mid-June	Mid-Oct.	White	1,270	For upland and rain-fed area
,,	Late Oct.	,,	1,592	
,,	Early Nov.	,,	1,464	
	Mid Nov.		1,942	
	Mid Nov.		1,718	Lodges less
	Late Nov.		2,034	
Mid. June	,,		1,660	

APPENDIX IV—*Continued*

1	2	3	4	5
8.	*R. 8. Benisar*	Sel. *Benisar*	,,	,,
9.	*Luchai × Gurmatia No. 18*	Hyb. (*Lichai × Gurmatia*)		,,
10.	*Luchai × Gurmatia × Burma No. 2*	Hyb. (*Luchai × Gurmatia × Burma No. 2*)		,,
11.	*R. 10 Chattri*	Sel. *Chattri*	,,	Early
12.	*R. 11 Dubraj*	Sel. *Dubraj*	,,	Med.
13.	*R. 14 Badsahabhog*	Sel. *Bodsahabhog*	,,	Late
14.	*R. 15 Chinoor*	Sel. *Chinoor*	,,	,,
15.	*Nungi × Nagkesar No. 1*	Hyb. (*Nungi × Nagkesar*)		Early
16.	*Nungi × Nagkesar × Sultuhurmatia No. 51*	Hyb. (*Nungi × Nagkesar × Sultugurmatia*)		Med.
17.	*Gurmatia × Nagkesar × Ajan No. 34*	Hyb. (*Gurmatia × Nagkesar × Ajan*)		Med.
18.	*Luchai × Nagkesar × Luchai No. 18*	Hyb. (*Luchai × Nagkesar × Luchai*)		Late
	MADRAS			
1.	*Co. 1*	Hybrid (natural cross from *GEB. 24*)	Winter	150
2.	*Co. 2*	Selection from *Poombalai*	,,	160
3.	*Co. 3*	Slection from *Vellaisamba*	,,	180
4.	*Co. 4*	Selection from *Anaikomban*	,,	200
5.	*Co. 5*	Selection from *Chinnasamba*	,,	180
6.	*Co. 6*	Selection from *Sadaisamba*	,,	190
7.	*Co. 7*	Selection from *Sadaisamba*	Winter	180
8.	*Co. 8*	Selection from *Anaikomban*	,,	200
9.	*Co. 9*	Selection from *Karasamba Red*	Autumn Spring	110
10.	*Co. 10*	Selection from *Kar variety*	,,	120

6	7	8	9	10
,,	,,		1,766	
	,,		2,076	Does not lodge
	,,		2,552	Non-shedding, lodges less
Mid-June	Early Nov.		1,240	Fine, scented
,,	,,		1,348	,, ,,
,,	Late Nov.		1,366	Fine, scented, small
,,	Early Dec.		1,532	,, ,,
,,	Mid-Oct.		1,690	Lodges less
Mid-June	Early Nov.		1,656	Dwarf
,,	Mid-Nov.		1,604	
,,	Late Nov.		1,566	Can be grown in heavy soils
June	Early Dec.	White	3,000 to 5,000	Resists stem borer
June-Oct.	Mid-Dec. Late Feb.	,,	3,000—5,000	
June	Mid-December	,,	4,000	
June-Oct.	Late Jan. Late Feb.	,,	4,000	Highly resistant to *Piricularia oryzae*, non-lodging
June	Mid. Dec.	,,	3,500—5,000	
June-Oct.	Early Jan. Early Feb.	,,	4,000	
June	Mid-Dec.	White	3,000—5,000	
June-Oct.	Mid-Jan. Early Feb.	,,		
June-Jan.	Sept.-April	Red	3,000	
June-Jan.	Oct.-April	White		

APPENDIX IV—*Continued*

1	2	3	4	5
11.	*Co. 11*	Selection from *Ayan samba*	Winter	
12.	*Co. 12*	Selection from *Sendhinayagam*	,,	200
13.	*Co. 13*	Selection from *Arupatham Kodai*	Autumn Spring	110
14.	*Co. 14*	Hybrid. Co. 3 × *Burma variety*	Winter	200
15.	*Co. 15*	Hybrid (*GEB. 24* × *ADT. 10*)	,,	210
16.	*Co. 16*	Same as *Co. 15*	,,	210
17.	*Co. 17*	Selection from *Vadan Samba*	,,	200
18.	*Co. 18*	Selection from *Vellaikar*	Autumn Spring	125
19.	*Co. 19*	Selection from *Sirumani*	Winter	210
20.	*Co. 20*	Selection from *Tella Sannavadlu*	Winter Spring	130 120
21.	*Co. 21*	Isolated from *Arupatham Samba*	*kar* (Autumn)	100
22.	*Co. 22*	Selection from *Manavari*	,,	115—120
23.	*Co. 23*	Selection from *Rangoon Samba*	,,	135
24.	*G.E.B. 24*	Mutant in *Konamani*	Winter	150
25.	*Co. 25*	Hybrid		195
26.	*Co. 26*	Hybrid		200
27.	*Co. 27*	Selection from *Pudupatti Samba*		160
28.	*Co. 28*	Selection from *Bangarutheegalu*		150
29.	*Adt. 1*	Selection from *Red Sirumani*	Winter	175 160
30.	*Adt. 2*	Selection from *White Sirumani*	,,	165 150
31.	*Adt. 3*	Selection from *Kuruvai*	Autumn	95
32.	*Adt. 4*	Same as *Adt. 3*	,,	100

6	7	8	9	10
June-Oct.	Mid-Jan. Late Feb.	,,		Weak straw
June	Late Jan.	,,	3,000	
June-Feb.	Sept.-April	,,	3,000	
June	Dec. end	,,	3,000 to 4,000	Stands submersion of 31-41 (3′-4′)
June-Oct.	Late Jan. Late Feb.	,,	—	Resistant to *Piricularia* stiff straw, bunched, earhead
June-Oct.	Late Jan. Late Feb.	,,	—	,,
June	Dec. end	,,	2,500	Stands drought, stiff straw with bunched earheads
June January	Mid-Oct. Mid-May	White	2,700	
June October	Late Jan. Feb. end	,,	—	Somewhat resistant to *Piricularia*
July January	Mid-Oct. Mid-May	,,	3,500	Responds to manuring
May-June	—	Red	2,400	
,,	—	,,	—	
,,	October	White	3,500	
June	Late Nov.	White	3,000—3,500	
July	January	,,	—	Blast-resistant
,,	,,	,,		Blast-resistant
July-Aug.	Dec.-Jan.	,,	3,000	
,,	December	Very light brown	2,000	
July September	Mid-Jan. Early Feb.	Red	3,000 2,000	
July September	Early Jan. Jan. end	White	2,800 2,400	
June	Early Sept.	White	3,200	
June	Mid-Sept.	White	3,800	

APPENDIX IV—*Continued*

1	2	3	4	5
33.	*Adt. 5*	Selection from *Nellore Samba*	Winter	180 170
34.	*Adt. 6*	Selection from *Red Ottadan*	,,	220
35.	*Adt. 7*	Selection from *White Ottadan*	,,	220
36.	*Adt. 8*	Hybrid (*Molakolukulu* × *White Sirumani*)	,,	150 140
37.	*Adt. 9*	Selection from *Poonkar*	Autumn	120
38.	*Adt. 10*	Selection from *Korangusamba*	Winter	165
39.	*Adt. 11*	Selection from *Nellore Samba*	,,	175
40.	*Adt. 12*	Selection from *Chitrakali*	Autumn	115
41.	*Adt. 13*	Selection from *Sannasamba*	Winter	160
42.	*Adt. 14*	Selection from *Vallaikar*	Autumn	115
43.	*Adt. 15*	Mutant from *Adt. 4*	,,	110
44.	*Adt. 16*	Seleetion from *Konakuruvai*	Autumn	115
45.	*Adt. 17*	Selection from *Mutnusamba*	Winter	165
46.	*Adt. 18*	Selection from *Vellaikuruvai*	Autumn	125
47.	*Adt. 19*	Selection from *Sarapalli*	,,	109
48.	*Adt. 20*	Hybird. ((*Adt. 3* × *Adt. 2*)	,,	105
49.	*Adt. 21*	Selection from *Vadan Samba*		150
50.	*Adt. 22*	Selection from *Vadan Samba*		155
51.	*Adt. 23*	Pure line		130
52.	*Adt. 24*	Selection from *Poona Samba*		150
53.	*Adt. 25*	Hybird ((*Adt. 2* × *Co. 4*)		165
54.	*Ptb. 1*	Selection from *Aryan*	Autumn	145

6	7	8	9	10
July September	Late Jan. Late Feb.	,,	2,800	
June	Feb. end	Red	2,000	
June	Feb. end	White	2,000	
July September	Dec. end Jan. end	,,	2,900 2,300	
June	Mid-Sept.	,,	4,000	
July	Early Jan.	,,	4,000	
July	Late Jan.	,,	3,400	
Early June	Mid-Sept.	,,	3,500	Stands irregular water supply
July	Early Jan.	,,	3,900	
Early June	Early Sept.	,,	4,000	
,,	,,	,,	—	
Early June	Early Sept.	White	3,700	
July	Early Jan.	,,	3,700	Stands somewhat submersion
June	Late Sept.	,,	3,600	
,,	Early Sept.	,,	3,800	
,,	,,	,,	4,200	
July-Aug. Aug.-Sept.		Red	—	
,,		Brownish white	—	
February	June	Red		
Sept.-Oct.	Jan.-Feb.	White	3,000	
July-Aug.	Jan.-Feb.	,,	3,000	
May-June	Mid-Oct.	Red	3,000	

Appendix IV—*Continued*

1	2	3	4	5
55.	*Ptb. 2*	Selection from *Ponnarayan*	Winter	135
56.	*Ptb. 3*	Selection from *Eravapandy*	,,	130
57.	*Ptb. 4*	Selection from *Velari*	Winter	140
58.	*Ptb. 5*	Selection from *Veluthariakayama*	Autumn	140
59.	*Ptb. 6*	Selection from *Athikaraya*	Winter	145
60.	*Ptb. 7*	Selection from *Parambuvattan*	Autumn	125
61.	*Ptb. 8*	Selection from *Thavalakannan*	,,	130
62.	*Ptb. 9*	Same as *Ptb. 8*	,,	145
63.	*Ptb. 10*	Same as *Ptb. 8*	Spring	100
64.	*Ptb. 11*	Selection from *Halliga*	Autumn	145
65.	*Ptb. 12*	Selection from *chitenni*	Winter	130
66.	*Ptb. 13*	Selection from *Kayama*	Autumn	135
67.	*Ptb. 14*	Selection from *Mascathi*	,,	130
68.	*Ptb. 15*	Selection from *Kavunginpoothala*	Winter	165
69.	*Ptb. 16*		,,	155
70.	*Ptb. 17*	Selection from *Jeddu Halliga*	Autumn	150
71.	*Ptb. 18*		Winter	130
72.	*Ptb. 19*	Selection from *Athikaraya*	,,	145
73.	*Ptb. 20*	Selection from *Chitenni*	,,	120
74.	*Ptb. 21*	Selection from *Thekkan*	,,	130
75.	*Ptb. 22*	Pure line		120
76.	*Ptb. 23*	,, ,,		120
77.	*Ptb. 24*	,, ,,		120

6	7	8	9	10
,,	October	,,	2,500	
Sept.-Oct.	Mid-Feb.	,,	1 800	
Sept.-Oct.	Feb. end	Red	2,200	
May-June	October	,,	2,700	
Sept.-Oct.	Feb. end	,,	2,000	
May-June	Sept. end	,,	2,400	Stands irregular water supply
,,	,,	,,	2,500	
,,	Mid-Oct.	White	2,000	Non-shedding and non-lodging
February	May	Red	2,000	
May-June	Mid-Oct.	White	2,500	
Sept.-Oct.	Mid-Feb.	Red	2,000	
May-June	Early Oct.	,,	2,500	
,,	Sept. end	White	2,500	
June-July	Early Jan.	,,	3,000	Crown in submersible areas, tall and stiff straw
,,	—	,,	3,000	
Early May	Mid-Oct.	Red	2,110	
Mid-Sept. Early Oct.	Late Jan. Early Feb.	Red		
Early Sept.	Mid-Jan.	Red		
April	September			
April	September			
,,	—			

APPENDIX IV—*Continued*

1	2	3	4	5
78.	*Ptb. 25*	,, ,,		120
78a.	*Ptb. 26*			
79.	*Ptb. 27*	,, ,,		150
80.	*Ptb. 28*	,, ,,		100
81.	*Ptb. 29*	,, ,,		95
82.	*Ptb. 30*	,, ,,		90
83.	*Ptb. 31*	Selection from *Elapapoochamban*		110
84.	*Ptb. 32*	Selection from *Auva Kari*		130
85.	*ASD. 1*	Selection from *Karasamba Red*	*kar*	115
86.	*ASD. 2*	Selection from *Karasamba White*	,,	110
87.	*ASD. 3*	Selection from *Veedhivadangan*	,,	130
88.	*ASD. 4*	Selection from *Kuruvai Kalayan*	,,	135
89.	*ASD. 5*	Selection from *Karthigasamba*		135
90.	*ASD. 6*	Selection from *Anaikomban*		170
91.	*ASD. 7*	Selection from *Karasmba Red*		110
92.	*ASD. 8*	Pure line		86
93.	*ASD. 9*	,, ,,		90
94.	*ASD. 10*		*Pishanam*	170
94a.	*ASD. 11*			
95.	*TKM. 1*	Pure line		120
96.	*TKM 2*	,, ,,		120
97.	*TKM. 3*	,, ,,		120
98.	*TKM. 4*	,, ,,		120
99.	*TKM. 5*	Selection from *Mana-kkattai*	*Swarnavari and navarai*	120
100.	*TKM. 6*	Hybrid *Co. 18* × *GEB. 24*	*swarnavari* and *navarai*	110
101.	*WND. 1*	Selection from *Palthondi*		

6	7	8	9	10
April	September			
September	January	Red		
April	September	"		
"	"			
"	"			
June	October	Red	2,500	
"	,	"	2,500	
May-June		"	3,600 to 4,500	
"		White	3,500 to 4,000	
"		Red	3,000 to 3,500	
September	January	"	2,000 to 2,500	
Mid-Oct.	Mid-March	White	3,000 to 4,000	
Early Sept.	Late Feb.	"	3,500 to 4,000	
Early June	Late Sept.	Red		
		"		
		"		
		White	3,100	Withstand considerable water stagnations in the initial stages
Aug.-Sept.	January	Red		
"	"	White		
May	September	White		
January	April	Dull white		
Jan.-May	April-Sept.	Red		Grows well in all kinds of soil, robust variety; fine-grained
Jan.-May	April-Sept.	White		Fine-grained
July	October	Red	3,000	

APPENDIX IV—*Continued*

1	2	3	4	5
102.	*WND. 2*	Selection from *Marathondi*		
103.	*MGL. 1*	Pure line		125
104.	*MGL. 2*	Selection from *Red Kayama*		122
105.	*Palur. 1*	Selection from *Garudan Samba*	Winter	
106.	*Palur. 2*	Selection from *Chitrakali*	Autumn	
	MYSORE			
1.	*S. 661*	Selection from *Coimbatore Sanna*		155—175
2.	*S. 699*	,,		155—160
3.	*S. 701*	,,		155—175
4.	*S. 139*	Selection from *Mysore Kaddi*		175—180
5.	*S. 718*	Selection from *Rathanchoodi*		165—175
6.	*S. 749*	,,		175—185
7.	*S. 246*	Selection from *Nagpur Sanna*		145—160
8.	*S. 924*	Selection from *Maharajabhogam*		175—185
9.	*S. 199*	Selection from *Alur Sanna*		135—155
10.	*S. 705*	Selection from *Bangara Kaddi*	Summer paddy	115
11.	*S. 317*	Selection from *Halubbalu*	,,	130
12.	*H. 497*	Selection from *Bangaratheegi*	,,	130
13.	*B. 281*	Selection from *Belikannan hegge*		150—165
14.	*B. 194*	Selection from *Musali*		145—155
15.	*B 16*	Selection from *Thogarina*		155
16.	*B. 1370*	Selection from *Puttabhatta*		155
17.	*B. 1399*	Selection from *Puttabhatta*		155

6	7	8	9	10
July	November	Red		
June	October	White		
,,	,,	Red	3100	
August	January	White	—	
June	September	,,	3100	
		White		Responds to good manuring
		,,		,,
		,,		,,
		,,		Tolerant to moderate alkalinity
		,,		Responds to good manuring
		,,		,,
		,,		Responds to good manuring tendency to lodge
		,,		Tendency to lodge
		,,		Tendency to lodge
		,,		Fairly drought-resistant
		,,		
		,,		
		,,		For heavy rainfall areas
		,,		,,
		,,		,,
		Red		,,
		White		,,

APPENDIX IV—*Continued*

1	2	3	4	5
18.	*S. 1089*	Hybrid *S. 705 × S. 661*		165—175
19.	*S. 1086*	Hybrid *S. 67 × S. 701*		170—175
20.	*S. 1084*	Hybrid *S. 67 × S. 701*		165—175
21.	*S. 1081*	Hybrid *S. 67 × S. 701*		160—165
22.	*S. 1073*	Hybrid *S. 169 × S. 661*		155—165
23.	*S. 1079*	Hybrid *S. 169 × S. 661*		140—145
24.	*S. 1092*	Hybrid *S. 705 × S. 661*		165—175
25.	*S. 1088*	Hybrid *S. 705 × S. 661*		180
	ORISSA			
1.	*B. 76*	Selection from *Benibhog*	Autumn	90
2.	*J. 1*	Selection from *Bobblihuta*	,,	105
3.	*J. 2*	Selection from *Mohl Kunchi*	Early winter	110
4.	*J. 3*	Selection from *Chhitti Kona*	,,	135
5.	*J. 10*			135
6.	*BAM. 12*	Selection from *Nayapur Sannam*		110
7.	*BAM. 13*	Selection from *Yana Kondnagi*		115
8.	*T. 56*	Selection from *Kala Kakkudia*	Winter	120
9	*T. 442*			135
10.	*J. 4*	Selection from *Sorumundabali*	Mid-winter	145
11.	*J. 5*	Selection from *Chudi*		145
12.	*J. 6*	Selection from *Ratanmali*		145
13.	*BAM. 14*			145

6	7	8	9	10
		,,		Monsoon variety
		,,		,,
		White		Monsoon variety
		,,		,,
		,,		,,
		,,		,,
		,,		,,
June-July	Nov.-Dec.			,,
	End of Sept.		1,000	Short-grained
	,,	White	1,200—1,500	Fine, for hilly tracts
	,,	,,	1,800	
	End of Oct. to Early Nov.	,,	2,400	Coarse
		,,	3,000	Coarse
	Mid.-Oct.	,,	1,200	Coarse
	,,	,,	1,500	
June-July	Late Nov.	White	2,600	
	End of Oct. to Early Nov.	,,	2,800	Coarse
	End of Nov.	,,	3,200	Medium grains
	,,	,,	3,800	,,
	,,	,,	3,000	
		,,	2,500	Medium

APPENDIX IV—*Continued*

1	2	3	4	5
14.	*BAM. 11*	Hybrid (*Boroponko Benibhog*)		150
15.	*T. 1145*	Selection from *Ussa*		140
16.	*T. 412*	Selection from *Badshabhog*	Winter	145
17.	*T. 812*	Selection from *Rangolata*	,,	145
18.	*T. 141*	Selection from *Soruchinnamali*	,,	150
19.	*J. 7*	Selection from *Karandi*	Late winter	165
20.	*J. 11*			165
21.	*BAM. 3*	Selection from *Bayyahunda*		155
22.	*BAM. 6*	Selection from *Ratnachudi*		160
23.	*BAM. 9*	Selection from *Mypali*		165
24.	*T. 90*	Selection from *Machakanta*	Winter	160
25.	*OBS. 7*	Selection from *T. 90*		165
26.	*T. 1242*	Selection from *Magura*		165
27.	*D.I. 3*	Natural hybrid in Japanese variety		120
28.	*D.I 4*	,,		130
29.	*SR 26B*	Selection from *Kalambank*		150
30.	*FR 13A*	Selection from *Dhalaputtia*	Winter	145
31.	*FR 43B*	Selection from *Bhetnasia*	,,	160
32.	*BAM. 15*	Selection from *Punai*		
33.	*T. 380*	Selection from *Banko*		
34	*T. 608*	Selection from *Basabati*		
	PUNJAB			
1.	*Jhona 349*	Selection	Autumn	130

6	7	8	9	10
	Late Nov.	,,	2,500	
	End of Oct. to Early Nov.	,,	2,800	Coarse
June-July	Late Nov.	,,	2,400	Short superfine
,,	,,	,,	2,800	Long superfine
,,	,,	,,	3,000	Fine
,,	End of Nov. to Early Dec.	,,	2,400	Coarse
		,,	3,000	Fine
June-July	Last week of November	White	2,800	Fine
,,	Early Dec.	,,	2,800	Fine
,,	,,	,,	3,000	Coarse
,	Late Nov.	,,	3,000	Fine
,,	,,	,,	3,000	Fine
,,	End of Nov.	,,	4,000	Coarse
January	April	,,	2,000	,,
,,	,,	,,	2,200	,,
		,,	2,000	Long, bold grains, salt-resistant
June-July	Late Nov.	Red	2,300	Coarse, flood-resistant
,,	,,	,,	2,500	,,
	End of Sept.	White		Resistant to drought
	Mid-Oct.	,,		,,
	Mid-Oct.	White		Fine
June-July	Mid-Oct.	White	2,700	Stands some salinity ; coarse, liable to lodge on rich soils

APPENDIX IV—*Continued*

1	2	3	4	5
2.	*Basmati 370*	Selection	Winter	140
3.	*Palman Suffaid 246*	Selection	Autumn	130
4.	*Ramjawain 100*	Selection		135
5.	*Phulputtas 72*	Selection		135
6.	*Lal Nakanda 41*	Selection		125
7.	*Dundar 43*			140
8.	*Sathra 278*			
	UTTAR PRADESH			
1.	*N. 22 Rajbhog*	Selection from *Rajbhog*	Autumn	90
2.	*N. 27*	Selection	,,	90
3.	*N. 32 Baljati*	Selection from *Baljati*	,,	84
4.	*A. 64 Hunsraj*	Selection from *Hunsraj*	,,	85
5.	*T. 136*	Hybrid (*T.1* × *T. 100*)	,,	93
6.	*T.1 Ramjiwain*	Selection from *Ramjiwain*	,,	98
7.	*N. 10B Basmati Pilibit*	Selection from *Basmati Pilibit*	,,	100
8.	*N. 12 Safeda*	Selection from *Safeda*	,,	100
9.	*T.3 Basmati*	Selection from *Basmati*	,,	115
10.	*T.21 Chawl*	Selection from *Chawl*	,,	110
11.	*T.43 Sondhi*	Selection from *Sondhi*	,,	102
12.	*T. 137*	Hybrid (*T.1* × *T.21*)	,,	100
13.	*T.138 Anjana Pilibit*	Selection from *Anjana Pilibit*	Autumn	100
14.	*T.9 Duniapet*	Selection from *Duniapet*	Winter	155
15.	*T.17 Bansi*	Selection from *Bansi*	,,	145
16.	*T.22A Bansi*	Selection from *Bansi*	,,	155

6	7	8	9	10
July	Mid-Nov.	,,	2,000	Superfine, long slender grains, scented
June-July	Mid-Oct.	,,	2,400	Long slender grains
		,,		Recommended for hilly tracts, medium
		,,		Medium rice
		,,		Coarse
		,,		Suitable for high altitudes ; coarse grains ; stiff straw
Mid-June	End of Sept.	White		Drought-resistant
,,	,,	,,		
,,	Mid-Sept.	,,		Coarse, drought-resistant
,,	,,	,,		Drought-resistant
,,	End of Sept.	,,		Fine
,,	,,	,,		,,
,,		,,		
,,		,,		
,,	Mid-Oct.	,,		Scented
,,	Early Oct.	,,		For saline tracts
,,	End of Sept.	,,		
,,		,,		
Mid-June		White		
,,	Mid-Nov.	,,		Long, fine, scented
,,	Early Nov.	,,		Long-fine
,,	,,	,,		

APPENDIX IV—*Continued*

1	2	3	4	5
17.	*T.23 Kala Sukhdas*	Selection from *Kalasukhdas*	,,	150
18.	*T.96 Anjee*	Selection from *Anjee*	,,	150
19.	*T.36 Jarhan*	Selection from *Jarhan*	,,	155
20.	*T.88 Chakia*	Selection from *Chakia*	,,	157
21.	*T.100 Benslot*	Selection from *Benslot*	,,	150
22.	*S. 8*			
23.	*S. 40*			
24.	*T. 79*			
	WEST BENGAL			
1.	*Chin 12 Satika*	Selection from *Satika*		
2.	*Chin 4 Dular*	Hybrid	*aus*	80—85
3.	*Chin 8 Marichbutty*	Selection from *Marichbutty*	,,	90
4.	*Chin 6 Dhairal*	Selection from *Dhairal*	,,	95
5.	*Chin 10 Charnock*	Selection from *Charnock*	,,	105—110
6.	*Bank 4 Bhutmuri*	Selection from *Bhutmuri*	,,	105—110
7.	*Bank 6 Ashkata*	Selection from *Ashkata*	,,	130—135
8.	*Bank 2 Jhangi*. 34	Selection from *Jhanji*	,,	125—130
9.	*Chin. 2 Kele*	Selection from *Kele*	,,	110—115
10.	*Bank. 1 Badkalam-Kati 65*	Selection from *Badkalamkati*	*aman*	135—138
11.	*Chin 5 Nagra* 41/14	Selection from *Nagra*	,,	165—170
12.	*Chin. 3 Bhasamanik*	Selection from *Bhasamanik*	,,	165—170
13.	*Chin. 23 Dudshar*	Selection from *Dudshar*	*aman*	165
14.	*Chin. 25 Latisali*	Selection from *Latisali*	,,	165

6	7	8	9	10
,,	Mid-Nov.	,,		Fine, scented
,,	,,	,,		Fine
,,		,,		
,,		,,		
,,	Mid-Nov.	,,		Coarse
May-June	July-Aug.	Amber	2,122	Medium, moderately resistant to *Helminthosporium*
,,	,,	Red	2,300	Coarse
,,	,,	Red	2,000	Coarse
,,	Aug.-Sept.	White	2,050	Fine
June	September	Red	2,400	Coarse, moderately resistant to *Helminthosporium*
,,	October	White	2,300	Coarse
,,	Sept.-Oct.	Amber	2,200	Coarse
,,	September	Red	2,270	Coarse.
June-July	October	White	2,300	Medium fine
,,	December	,,	3,040	Medium
,,	,,	,,	3,280	
June-July	Nov.-Dec.	White	3,040	Medium coarse
,,	,,	,,	2,950	Oval-shaped, coarse; drought-resistant

Appendix IV—*Continued*

1	2	3	4	5
15.	*Chin. 27 Jhingasail*	Selection from *Jhingasail*	,,	160—165
16.	*Chin. 11 Kalma-222*	Selection from *Kalma*	,,	170
17.	*Chin. 17 Badshahbhog*	Selection from *Badshahbhog*	,,	170
18.	*Chin. 29 Inderasail*	Selection from *Indrasail*	,,	170
19.	*Chin. 7 Patnai-23*	Selection from *Patnai*	,,	170
20.	*Chin. 9 Patnai-298*	Selection from *Patnai*	,,	170
21.	*Chin. 37 Kalamakati-147*	Selection from *Kalamkati*	,,	170
22.	*Chin. 15 Seetasail-499*	Selection from *Seetasail*	,,	170
23.	*Chin. 13 Rupsail 859/37*	Selection from *Rupsail*	,,	170
24.	*Bank 35 Randhunipagal*	Selection from *Randhunipagal*	,,	170
25.	*Chin. 39 Kataribhog*	Selection from *Kataribhog*	*aman*	165—170
26.	*Chin. 31 Tilakkachary*	Selection from *Tilakkachary*	*aman* (late)	180
27.	*Chin. 19 Kumargore*	Selection from *Kumargore*	,,	185
28.	*Hybrid 84 Asr 108/1 × Patnai-23*	Hybrid (*Asr 108/1 × Patnai-23*)	,,	180-185
29.	*Bank. 3 K × 136 hybrid*	*Hybrid* (*Kataktara × Indrasail*)	*aman*	140-144
30.	*Bank37 Churnakati*	Selection from *Churnakati*	,,	130-135
31.	*Bank 9 Maltu*	Selection from *Maltu*	,,	144—150
32.	*Bank 25 Nonarams-*	Selection from *Nonaramsail*	,,	150—155
33.	*Bank 31 Raghusail*	Selection from *Raghusail*	*aman* (late)	168—170
34.	*Bank 21 Ajan-246*	Selection from *Ajan*	*aman*	158—160
35.	*Bank 11 Harkum*	Selection from *Harkum*	,,	155—160
36.	*Bank 13 Badkalamkati 141*	Selection from *Badkalamkati*	,,	160
37.	*Bank 15 Boldar*	Selection from *Boldar*	*aman*	156—160

6	7	8	9	10
June	,,	,,	2,460	Long, drought-resistant to some extent
,,	December	,,	2,950	Long
,,	,,	,,	3,000	Fine, oval, scented
,,	,,	,,	2,780	Medium coarse
,,	,,	,,	3,690	Long, bold
,,	,,	,,	3,530	
,,	,,	,,	3,120	Medium
,,	,,	,,	2,000	Fine
,,	,,	,,	2,000	Saline-tolerant
,,	,,	,,	2,780	Small, fine, scented
,,	,,	,,	3,400	Fine, scented
,,	,,	,,	2,840	Coarse
,,	Dec.-Jan.	,,	2,950	Grown in saline area
,,	,,	,,	3,300	Can resist submergence up to 6 ft.
June-July	October	,,	2,580	Medium
,,	,,	,,	2,200	Fine
,,	Nov.-Dec.	Red	2,560	Coarse
,,	,,	White	3,100	Fine
,,	Dec.-Jan.	,,	3,520	Coarse
,,	Nov.-Dec.	,,	3,000	Long
,	,,	,,	2,760	
,,	,,	,,	2,870	
June-July	Nov.-Dec.	White	2,900	Coarse

APPENDIX IV—*Concluded.*

1	2	3	4	5
38.	*Bank 17 Dahijira*	Selection from *Dahijira*	,,	158—160
39.	*Bank 19 Kaladubraj*	Selection from *Kaladubraj*	,,	158—160
40.	*Bank 23 Kalikalma*	Selection from *Kalikalma*		158—160
41.	*Bank 27 Manikkalma*	Selection from *Manikkalma*	*aman* (late)	160—165
42.	*Bank 29 Sindurmukhi*	Selection from *Sindurmukhi*		165
43.	*Bank 33 Bansmoti*	Selection from *Bansmoti*		
44.	*Bank 5 Badkalamkati*	Sel. *Badkalamkati*	*aman*	138
45.	*Chin 25* (*Nizersail*)	Sel. *Nizersail*		170

6	7	8	9	10
,,	,,	Red	3,100	Coarse
		White	3,000	Medium
		Red	3,116	Medium
		White	3,200	Coarse
		,,	3,400	Coarse
		,,	2,700	Oval, fine, scented
June-July	October	,,	2,200	Fine white rice
June	December	,,	2,790	Hard grains

APPENDIX V
CHARACTERS AND PERFORMANCE OF SOME GREEN MANURE CROPS

Sl. No.	Name	Local name	Average Yield of green matter in lb./acre (8-week stage)	Moisture percentage	Quantity of dry matter in lb./acre	Yield of seed in lb. per acre	Nitrogen percentage on dry weight basis	Resistance to Drought	Resistance to Water-logging	Remarks
1	2	3	4	5	6	7	8	9	10	11
1.	*Sesbania aculeata*	*dhaincha*	15,362	80.3	3,026	567	2.838	X	XX	Quick-growing; gets woody within 2 months
2.	*S. speciosa*	Wild *dhaincha*	6,893	84.5	1,068	477	2.289	X	XX	Initially slow-growing; suitable for all seasons
3.	*S. sericea*	..	15,313	71.2	4,410	564	2.961	X	XX	Compares with *dhaincha* in all respects
4.	*Crotalaria juncea*	Sunnhemp	16,934	72.7	4,622	797	2.029	XX	..	Suitable only to high lands; quick-growing
5.	*C. brownei*	..	4,080	74.0	1,060	962	5.107	X	..	Initially slow-growing, suitable for *rabi* season also; profuse seeding
6.	*C. usarmoensis*	..	7,098	78.8	1,504	1088	5.352	X	..	do.
7.	*C. striata*	..	3,722	77.4	851	1033	3.946	X	..	do.
8.	*Phaseolus semi-erecutus*	..	9,446	81.9	1,709	378	2.136	X	XX	Highly succulent even after 3 months; seed-collection is difficult as the pod bursts as soon as it matures
9.	*Phaseolus aureus*	*mung*	7,650	83.8	1,239	604	1.960	XX	..	Quick-growing and early maturing
10.	*P. aureus* (Type No. 1)	do	5,950	78.4	1,285	353	2.112	X	..	Earlier than the above
11.	*P. trilobus*	*pillipesara*	4,729	79.0	991	190	1.948	X	..	Highly succulent; grows vigorously with pre-monsoon showers
12.	*Cassia leschenaultiana*	..	5,019	65.0	1,756	154	2.264	X	..	Suitable for high lands only; slow-growing

1	2	3	4	5	6	7	8	9	10	11
13.	*C. tora*	*wild cassia*	3.232	66.0	1,098	467	2.651	X	X	A common roadside weed
14.	*C. mimosoides*	..	3,740	76.7	871	168	4.025	X	X	Highly succulent even at later stages; slow-growing
15.	*C. occidentalis*	..	3,092	76.0	742	410	2.464	XX	..	Roadside weed
16.	*Aeschynomene americana*	..	8,850	82.6	1,039	1120	2.996	X	XX	Initially slow-growing, stands water-logging; profuse seeding
17.	*Vigna sinensis*	cowpea	12,591	87.1	1,624	606	2.744	X	..	Quick-growing, suitable for both seasons
18.	*Cyamopsis posoralioides*	*guar*	6,423	75.0	1,605	331	4.072	X	..	Not suitable for low lands
19.	*Tephrosia purpurea*	wild indigo	3,007	69.1	1,929	327	3.715	XX	..	Poor growth; establishes as a self-sown crop; highly drought-resistant
20.	*T. noctiflora*	..	1,752	66.0	595	..	3.801	XX	..	do.
21.	*Centrosema pubescens*	..	3,710	61.6	1,424	224	2.317	XX	..	Slow-growing; a good cover crop
22.	*Calopogonium mucunoides*	..	3,740	76.4	882	542	3.069	XX	..	Slow-growing; a good cover crop, with profuse seed-setting
23.	*Lathyrus sativus*	*Khesari*	3,398	81.7	584	502	..	X	..	Suitable for *rabi* season only
24.	*Melilotus alba*	*senji*	3,676	79.7	746	132	2.623	X	..	do.
	Leafy material									
25.	*Gliricidia maculeata*	..		Useful for roadside planting			3.031			Gives about 50 lb. of leafy matter per plant from third year onwards
26.	*Indigofera teysmanii*	..		63.3	do.		3.710			Recently introduced in Madras State

NOTE: Data recorded at the Central Rice Research Institute, Cuttack, under the Green Manuring Scheme sponsored by Indian Council of Agricultural Research (Average of 2 years)

X Shows partial resistance
XX Shows complete resistance

GLOSSARY

Abi — A term used in Hyderabad for the crop sown in May-June and harvested in November-December. Also refers to the crop season

Ahu — A term used in Assam for autumn and summer rice

Aman — A term used in many states for winter rice

Aus — A term used in West Bengal for autumn rice

Babool — *Acacia arabica*

Bakhar — A blade-harrow ; also called *guntaka*

Bao — Medium and deep water winter rice in Assam

Barra — A term used in Madhya Pradesh for poor soil

Beali — A term used in Orissa for autumn rice

Berseem — *Trifolium alexandrinum*

Beushan — A term used for interculture of broadcast rice in standing water in Orissa ; same as *biasi* in Madhya Pradesh

Bhadi — A term used in Uttar Pradesh for autumn rice; also called *kuari*

Bhang — *Cannabis sativa*

Biasi — A term used in Madhya Pradesh ; same as *beushan*

Bidha — A tined harrow

Boro — A term used in West Bengal for spring rice

Bund — Field embankment or levee

Chalkas — A term used in Hyderabad for sandy loam red soils

Chapari lands — A term used in Assam for heavily flooded lands

Chatra — A disease on rice reported from Bihar, said to be due to sulphur deficiency ; also known as *dakhina* or *ukra*

Cole cultivation — A special method of rice cultivation in Kerala

Dakhina — Disease on rice reported from Bihar said to be due to sulphur deficiency ; same as *chatra, ukra*

Dalua — A term used in Orissa for spring or summer rice

Daw — A knife or sickle

Dhaincha — *Sesbania aculeata*

Desi — Indigenous

Domatta — A term used in Madhya Pradesh for medium soils

Dorsa — A term used in Madhya Pradesh for dark grey soils

Gonag — A term for wild rice in Bombay

Gram Panchayat — Village council

Guar — *Cyamopsis psoraloides*

Gundhi bug — A stink bug—*Leptocorisa* spp.

Guntaka — A blade-harrow ; same as *bakhar*

Haine — The first crop of rice in Mysore sown in June

Hoar — A term used in Assam for low-lying basins which retain water almost throughout the year

Hodding — A term used in Punjab for interculture ; same as *biasi* or *beushan*

Jhum — A term used for shifting cultivation in Assam

Kallar — A term used in many states for saline and alkaline soils; also called *reh*, *Usar* and *Kharvat*

Kankar — A term used in Madhya Pradesh for black heavy clay soils

Kans — *Saccharum spontaneum*

Kar — Same as *kuruvai*

Khadar — A term used in Uttar Pradesh for riverine soils formed by alluvial deposits

Khari — A term used in Kerala for peaty soils

Kharvat — Same as *kallar*, *reh*, *usar*

Khesari — *Lathyrus sativus*

Kresek — A term used for bacterial disease on rice reported from Indonesia

Kuari — A term used in Uttar Pradesh for autumn rice; also called *bhadi*

Kulthi — *Dolichos biflorus*

Kuruvai — A term used in Madras for autumn rice ; also called *kar*

Manavari — A term used in Madras for first crop season December-February in tank-fed areas

Mar — A term used in Uttar Pradesh for wet lands which are imperfectly drained and are clay loams with sufficient organic matter

Matasi -- A term used in Madhya Pradesh for fine-grained yellow loam soils

Moi — A wooden or bamboo implement shaped like a ladder used for levelling the fields

Morand II — A term used in Madhya Pradesh for clayey soils

Mundakan — A term used in Kerala for second crop sown in September-October and harvested in January-February

Navarai — A term used in Madras for second crop season January-May in tank-fed areas

Neem — *Azadirachta indica*

Paiyes — Rice pudding

Pansukh — A physiological disease of rice

Pat land — A term used in Orissa for lands in coastal areas with acidic soils

Pillipesara — *Phaseolus trilobus*

Pishanam — A term used in Madras for short or medium-duration second crop grown in September-October to February-March ; also called *thaladi*

Podu cultivation — A term used in some states for shifting cultivation ; same as *jhum*

Pulao — A preparation made with rice

Punja — A term used in Kerala for third crop sown in December-January and harvested in March-April

Rab — A term used in Bombay State for heaping and burning organic matter in the seed-bed

Rabi — A term used for winter cropping in North and Eastern India

Ragi — *Eleusine coracana*

Ran mutki — *Phaseolus trilobus*

Regur — A term used for black cotton soil in Andhra Pradesh

Reh — A term used in many states for saline and alkaline soils; also called *kallar*, *usar* and *kharvat*

Sali — A term used in Assam for winter rice

Samba — A term used in Madras for medium or long-duration crop grown in August to January

Sarrad — A term used in Orissa for winter rice

Sarva — A term used in Andhra Pradesh for winter rice season

Sathi — A crop of 60 days duration

Sawai — A system of giving seed on loan to be returned with 25 per cent. interest in kind

Sehar — A term used in Madhya Pradesh for loamy soils

Senji — *Melilotus* spp.

Tabi — The second crop in Hyderabad grown in January-May and also the crop season

Tehsil — A sub-division in a district

Terai — A term used for the tract lying at the foot of the Himalayas

Thaladi — A term used in Madras for short and medium-duration crop grown in September-October to February-March ; also called *pishanam*

Thana — Police Station

Udbatta — Disease of rice reported from Orissa, Hyderabad and Mysore

Udu cultivation — A particular system of rice cultivation in Kerala, Madras and Assam where two varieties of rice of different durations are grown mixed

Ufra — Disease of rice reported from West Bengal, Hyderabad and Uttar Pradesh

Ukra — Disease of rice reported from Bihar, said to be due to sulphur deficiency ; same as *chatra* and *dakhina*

Usar — A term used in many states for saline and alkaline soils ; also called *kallar*, *reh*, and *kharvat*

Val — *Dolichos lablab*

Viruppu — A term used in Kerala for the first crop season April-September

Waingan — A term used in Bombay State for hot weather rice

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